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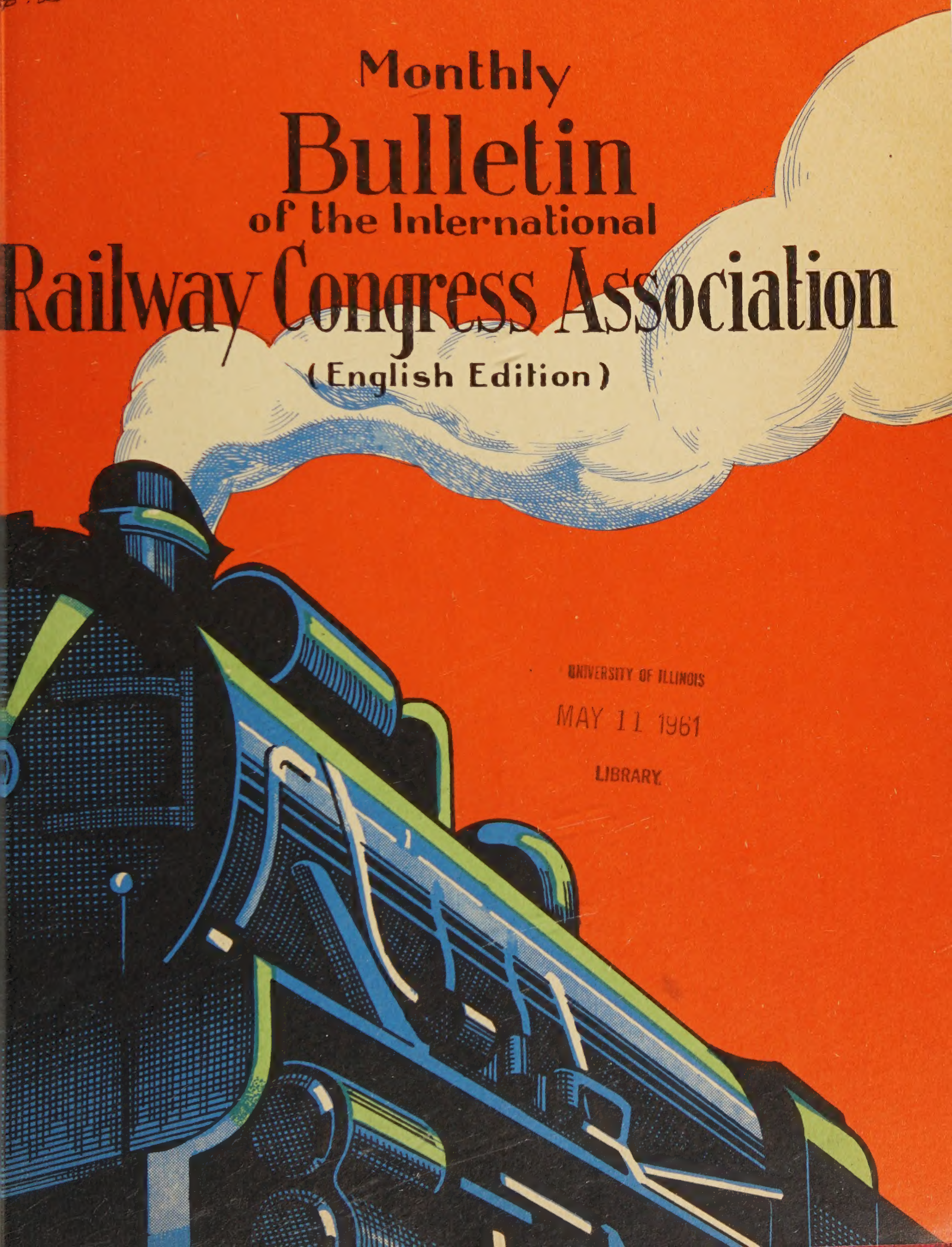
(English Edition)



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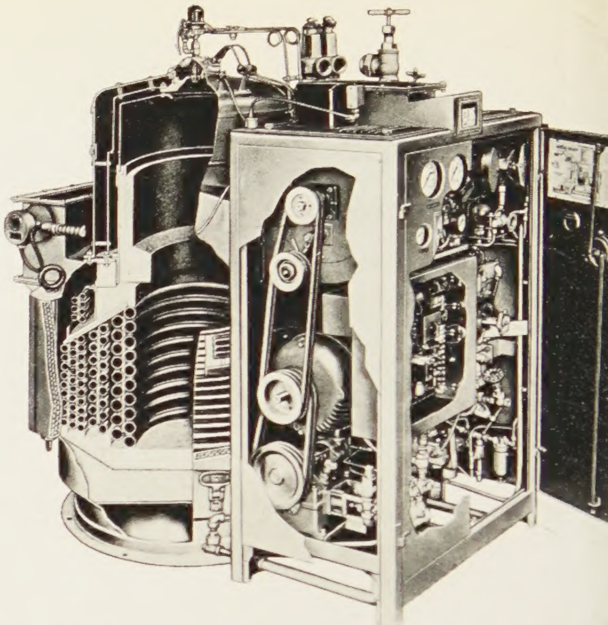

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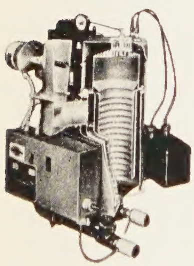

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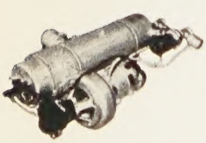

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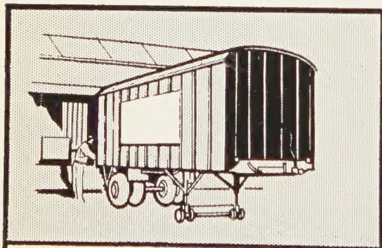

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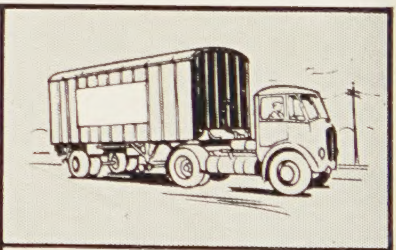

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OF THE

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(ENGLISH EDITION)

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BULLETIN
OF THE
INTERNATIONAL RAILWAY CONGRESS
ASSOCIATION
(ENGLISH EDITION)

[656 .254]

Some thoughts on cab signalling,

by Dr. Eng. Matteo B. Cirenei,

Capo Servizio dell'Azienda Tranviaria Municipale di Milano.

(*Revue de l'Union Internationale des Transports Publics*, Vol. IX, No. 2, VII. 1960.)

SUMMARY. — *The adoption by railways of the block system for the automatic operation of signals raises the level of security of operation in so far as concerns the lineside equipment.*

However, to achieve an all-round increase in the security level, it is necessary to ensure that information received on the locomotive shall be acted upon, irrespective of any human intervention.

This may be achieved by means of appropriate equipment for the repetition of signals on the vehicles, and for the automatic control of speed; information may be transmitted from the track to the vehicle either continuously or at given intervals; the use of either of these systems has an influence on the distance to be maintained between trains for any given arrangement of signals.

In particular, it is concluded that in the light of the limiting assumptions on which this comparative study is based, continuous repetition of signals is to be preferred without the addition of automatic speed control.

I. Introduction.

Today more than ever before the majority of railway administrations are embarked on the planning and putting into effect — at more or less short notice — of schemes for modernising their services in order to meet the ever-growing competition from other forms of transport.

The objective of these schemes is thus to improve the quality of service offered to railway users while at the same time if possible reducing its net cost (1).

This objective can only be achieved by adopting means which, by increasing the efficiency of the methods and equipment of transport, improve the productivity of the line.

The adoption of a device which automatically maintains the specified distance between trains (block system) is in accordance with this precept, since :

— it increases the capacity of a line while at the same time reducing the number of staff required to ensure the spacing of trains; since it is no longer necessary to maintain in each « block post » staff specially allocated to receive requests for « line clear » (transmitted manually by some device or other) and to return suitable replies (by the same means);

— it increases the safety of operation by eliminating any human intervention; the spacing of trains is assured by equipment so interlocked as to render wrong operation impossible.

(1) It should be mentioned that sometimes this objective is unattainable, not because the technical or economic reasons behind any given course of action no longer exist, but because it is impossible to achieve the anticipated economies, either because it is not possible to effect reductions of staff or because the latter cannot be transferred to work other than that specified in the working agreements in force.

II. **Automatic train control methods.**

Any device used for automatically maintaining the required distance between trains only increases the factor of safety of operation in so far as the lineside equipment is concerned; it cannot be considered that an all-round improvement in safety factor has been achieved unless all powered vehicles are provided with means for automatic and correct responsive action in accordance with the lineside signals, independently of any human agency (2).

For this to be achieved the various track conditions must be reproduced by distinct changes in the supply to the track circuits or other equipment specially provided for the purpose; the apparatus on the vehicle will thus be able to receive and select distinct pieces of information corresponding to each lineside signal.

In such case, the vehicle equipment will also be able to check that the necessary operations have been carried out by the driving staff correctly and at the proper time; failing which it will automatically initiate security measures such as, for example, emergency braking of the train.

Automatic control of train movement is thus achieved by means of two successive operations : the first being the repetition on the vehicle of information transmitted by the track; the second is the check that the driving staff have properly responded to the information received.

As regards the repetition itself, it may be accepted that at the present time the best results are obtained by utilising for feeding the track sections coded impulse trains in varying sequences, each one of which corresponds to a given condition of the section.

The signal is in fact transmitted to the vehicle uninterruptedly, and corresponds continuously to the track conditions, any change in which is received immediately. The movement of trains (which alone receive the repeated signals) is therefore flexible and is in no way governed by the length of sections; so that the device may be utilised to its maximum capacity without the slightest reduction in the degree of safety.

However, when to repetition of signals is added the automatic control of operations normally performed by the driver, the resultant installations may impose too many restrictions on train movement.

In fact, in such case the reception of a signal on the vehicle must be followed by action directed towards regulating the movement of the train in accordance with the line conditions.

Now, if transmission is of the continuous type, such action cannot be translated into any predetermined system of non-continuous control of the driver's vigilance (such as, for example, pressure on a button at given intervals) but must consist in reproducing the restrictive conditions which such a signal imposes on train movement for as long as it is being received.

On the other hand, the use of repeating equipment installed only at selected points, and arranged also to transmit a certain number of pieces of information (corresponding to various track conditions) offers scope for greater operating flexibility, since it enabled a reasoned control of vigilance to be obtained, i.e. it confers no obligation to observe rigidly and continuously certain given conditions of running (such as reduction in speed between certain previously established limits).

Furthermore, it should be noted that equipment of this kind can be used whether or not the condition of the sections is controlled by standard type track circuits (or similar devices).

In this way « intermittent » or « non-continuous » transmission of information may be effected from the track to the vehicle. Various types of coupling are available for this, but it would appear preferable to use inductive coupling, either because it offers a high degree of safety in operation or because it offers the possibility

(2) In the absence of automatic control, the custom has become established of employing a driver's assistant; the possibility of avoiding the use of this assistant enables operating economies to be achieved which justify the financial outlay required for the installation of the control equipment.

of transmitting a considerable number of indications which are completely distinguishable from each other (3).

It is assumed in what follows — in which attention is given to certain aspects of the influence which may be exerted on the capacity of the line by the use of « continuous » or of « intermittent » repetition — that the latter can be provided by apparatus giving a high degree of operating safety comparable to that of apparatus for continuous repetition, even if the track circuits are not controlled by current pulses.

It is further assumed that a check can be kept on the proper functioning of the apparatus on the track; i.e. that the removal of a piece of equipment or any part thereof produces an indication drawing urgent attention to the signal concerned (either directly or by means of other equipment such as, for example, the block apparatus).

Finally, it is assumed for the sake of simplification that the block sections are always protected by lineside signals.

III. Types of train control systems.

The control of train movement in conformity with its line conditions is dependent on a more or less intensive control of the driver's actions.

Hence, vigilance systems may be divided into two basic types according to their method of functioning :

A. — Devices whose action covers the production on the vehicle of a visual, and if necessary, audible repetition of the track signals; such repetition may however be completed by a check on the actions of the driver.

B. — Devices whose action covers transmission to the vehicle of information relating to the condition of the track without however repeating it to the driving staff. This means that the device checks that the driver carries out the required action after having himself directly observed the lineside signals; visual repetition may be provided if necessary, but nothing more.

As regards the form of control exerted over the operations performed by the driving staff, vigilance systems may be divided into two groups as under :

1. — Apparatus producing a check on vigilance; i.e. it checks the state of attentiveness of the driving staff by requiring such staff to operate some suitable device;

2. — Apparatus producing a check on speed; i.e. it checks the actual speed of the train at certain predetermined moments during the braking period (4).

This latter is not in any way a rigid subdivision since apparatus may be devised whose action is a combination of a check on vigilance (group I), and a check on speed (group II).

Failure to take correct action on the receipt of information from the track (which may also be recorded on the speedometer chart if required) may if necessary produce automatic braking of the train.

IV. Characteristics of vigilance and speed control.

If a simple control of vigilance is deemed sufficient, the automatic brake application taking place immediately in the rear of the signal when the driver has failed to take action ensures that the train is brought to a stand before it reaches the stop signal ahead.

From this viewpoint, it would seem sufficient to transmit the information from the ground to the vehicle only at the signal

(3) It is probably unnecessary to draw more than passing reference to the fact that the « intermittent » system can, in its simplest application provide indications similar to that of a *train-stop*, i.e. repetition of « track occupied » with corresponding controlling action on the vehicle.

(4) In its simplest form this check on speed could be effected by a check on braking which might consist, for example, in recording the brake pipe pressure at certain predetermined moments during the braking period.

itself, without employing protective sections, such as, for example, a protective track circuit (5) in advance of the stop signal (Fig. 1).

However, it must be mentioned that such a solution does not give sufficient security, since it is only the degree of vigilance exhibited by the driver which is checked, and when this has been done the train may continue on its way at the same speed and so run past the stop signal at full speed.

Fig. 1. — Check on vigilance. The information is conveyed to the vehicle immediately opposite the warning signal preceding the stop signal « at danger ».

To avoid this, it may be advantageous to supplement the simple check on vigilance by a check on speed.

In its simplest form this control may be provided by automatic application of the brakes when the train runs past a stop signal. Such a scheme may be put into effect with control systems of both « intermittent » and « continuous » types and in any case implies a protective track circuit in advance of the stop signal and having a length equal to the greatest braking distance of any trains running on the line in question (Fig. 2).

If it is required to improve the control of vigilance still further, an intermediate control of speed may be imposed between the warning signal and the stop signal. This may be either a distance control or a time control (applicable in the latter case to the fastest train) as soon as the motor vehicle has been informed that the line is blocked. The speed will have to be controlled at a value intermediate between full speed and stop. In no case should this value be too low where the intermittent signal is used, in order to avoid an excessive reduction in speed, especially if the stop signal has meanwhile cleared. On the other hand, it should not be too high, otherwise there is a possibility that the stop signal at danger may be passed at excessive speed; which would require an excessively long protective track circuit (Fig. 3).

Fig. 2. — Check on vigilance reinforced by control of speed. Automatic application of brakes occurs immediately on passing stop signal at danger, which is provided with a protective track circuit.

In all cases, it is essential for the length of the protective track circuit to be less than that established when considering the case of figure 2. The solution given by figure 3 is in principle applicable with either an intermittent or a continuous system, but

(5) It may be mentioned in passing that a protective track circuit is used in certain applications to maintain safe spacing between two trains following each other in the same direction, and is more economical than the provision of a clear section. It is not in fact distinguished by its own signal or, on lines equipped with coded automatic block, by individual coding circuits; in such case, it may normally be fed with steady currents on to which are superimposed — over the period of repetition on the locomotive — the code in force in the section in advance at the moment when it is occupied by the train. So long as this occupation lasts, the section in rear (and the signal protecting it) is subjected to maximum restriction. When the last axle of the train leaves the overlap track circuit, this section in rear and the entry signal return to the « caution » condition.

appears better suited to the former, which, as already stated, seems to offer greater flexibility in operation than the continuous system from the speed control viewpoint.

On the other hand, when the braking distances of trains are very long and it is

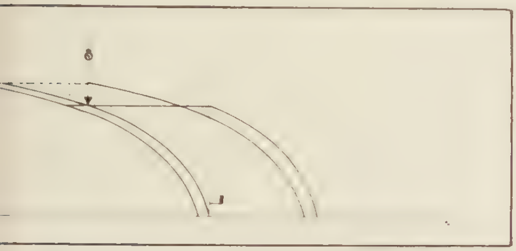

Fig. 3. — Check on vigilance reinforced by control of speed. The insertion of one or more intermediate speed controls, between the warning signal and the stop signal enables the check on vigilance to be more effectively reinforced.

in consequence really economical to reduce the length of protection as much as possible, it would appear desirable to have recourse to more than one intermediate control of speed in the shape of controls either of distance or of time (Fig. 4).

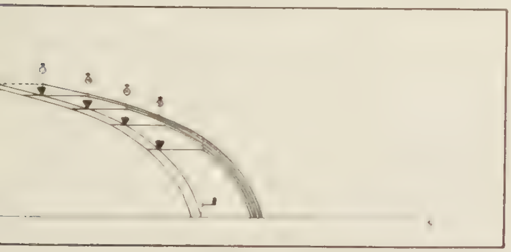

Fig. 4. — Control of speed. This takes its most effective form when there are an infinite number of controlled levels of speed.

All these considerations apply to a line on which the signalling system only provides for a single warning indication.

Warning signals have been mentioned in their simplest form so that the subject might be treated in a fairly general way, notwithstanding the fact that in their different applications stop signals are used either with separate or with combined warning signals.

In any case, it has not been considered advisable to do away with the lineside signals, since apart from certain modern lines of no great size, (e.g. the Stockholm underground), the diversity of installations and rolling stock gives the impression that at the present time elimination of these signals is not practicable.

V. Influence of the type of repeater on the distance between trains in normal running.

It is now proposed to examine the influence of the two repeating systems, intermittent or continuous, on the distance between trains, or, for a given track capacity, on the numbers of signal locations required per kilometre; these locations being defined by the amount of cable and apparatus it is necessary to provide for them (6).

In what follows, consideration will be given to some typical signal combinations by setting down side by side the effects of the two systems — intermittent and continuous — on each combination, i.e. comparison will be effected over the same block sections as defined by the lineside signals.

Case 1/a. — Stop signals with associated warning signal and protective track circuit (Fig. 5).

(a_1) *Continuous system* (7).

With reference to figure 5-a), consider the stretch of track shown; different subdivisions, with sections having lengths greater than the braking distance, each fed with coded

(6) It may be mentioned in passing that any given vehicle equipment for the automatic interpretation of the indications received may be actuated equally well by either the intermittent of the continuous system.

(7) Throughout what follows the indices « c » or « p » have been subjoined to the various symbols to denote the « continuous » or « intermittent » systems respectively.

currents and provided with a protective track circuit.

These sections are connected « in cascade » in order to preserve the required distance between trains; each lineside signal is a « stop signal with associated warning signal ».

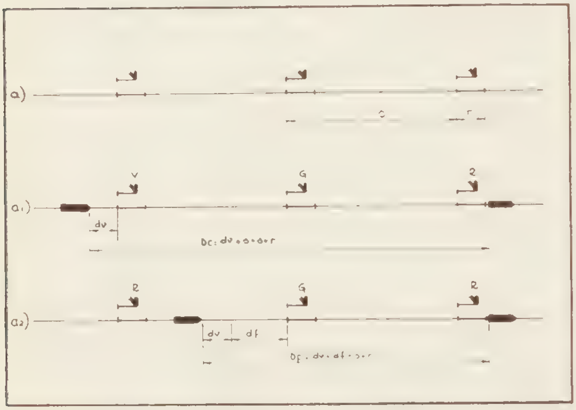

Fig. 5. — Train spacing obtained with lineside stop signals with associated warning signals; each signal has a protective track circuit.

In these conditions, the minimum distance between two trains under normal sighting conditions with « line clear » (more exactly, with an intervening clear section) is given by the equation (Fig. 5-a_1) :

$$D_c = d_v + 2s_c + r \qquad (1)$$

where :

r = length of protective track circuit = half the braking distance increased by a certain length of track s_r to allow for the reaction time of the driver and the time delay of the equipment [8];

d_v = sighting or « response » distance (150 m = 164 yds);

s_c = length of a section of main line.

One deduces from formula (1) :

$$s_c = \frac{D_c - K_c}{2} \qquad (2)$$

where $K_c = d_v + r$.

Again, if :

V = the schedule speed of the slowest train (in m/sec);

T = the required minimum interval of time (in seconds) between two successive trains running under the maximum speed conditions allowable :

then $D_c = V \cdot T$, so that formula (2) becomes :

$$s_c = \frac{V \cdot T - K_c}{2}\,. \qquad (2')$$

In order to simplify the bases of comparison, it would now appear opportune to introduce a term easy to define in the two systems considered here; this term is the number « p » of « signal locations per unit of distance ».

Is is then necessary to express the «weight» attributable to the lineside equipment in any section — apart of course from the stop signal which protects it — and to express this « weight » as a percentage of the « weight » of the latter.

The term « weight » — which is in general use — may be associated, for example, with the cost or the number of

(8) This is because it is considered that, since there is automatic control of speed, the maximum speed is already suitably reduced at the moment when the warning signal is received; so that the stopping of the train after running into some already occupied section would require a shorter braking distance.

It has been conventionally assumed in the present case that, following receipt of the warning, the speed is reduced in such a way that the distance required for stopping a train which has run into an occupied section is equal to half the length of track presumed to be necessary for braking from maximum speed.

In drawing the diagrams it has been assumed that r = 600 m (656.2 yds) and s_r = 100 m (109.36 yds).

items of equipment cabled and in operation; the cost or the number of items relating to the stop signal naturally being taken as unity.

In the case under consideration, the amount of cables and equipment necessary for a protective track circuit may be taken as being some 30% of the amount required for the stop signal.

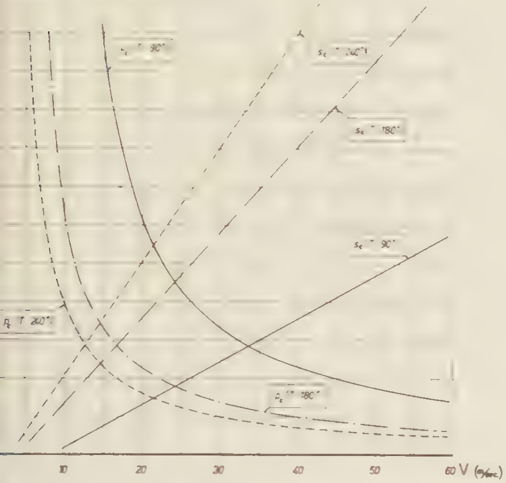

Fig. 6. — Case 1/*a*. — Continuous repetition. Curves of variation of s_c and p_c as functions of V.

From this it results that :

$$p_c = \frac{1 + 0.3}{s_c} \cdot \qquad (3)$$

It may be of interest to see how s_c and p_c vary firstly as a function of V for a given value of T (curves Fig. 6), and then as a function of T for a given value of V (curves Fig. 7).

It should be emphasised that in the present case the warning signal is given at a distance greater than that required : it is not therefore given at the appropriate time.

(a_2) *Intermittent system.*

Still with reference to the stretch of track in figure 5-a, let it be assumed that each section is fed with a steady current and that repetition in the locomotive is of the « intermittent » type.

In such case, without modifying the number or arrangement of the sections it is possible to install the repeater on the track at a point where it can provide indications to the train, not at the commencement of the length (assumed to be longer than the braking distance) but as an emergency signal at a distance d_f from the stop signal,

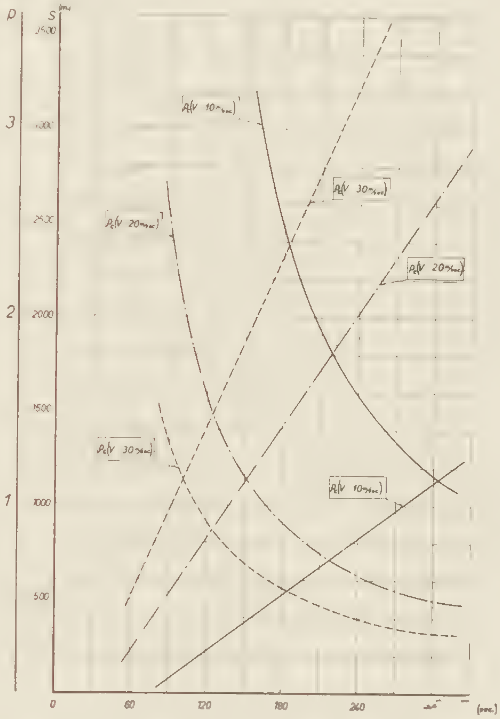

Fig. 7. — Case 1/*a*. — Continuous repetition. Curves of variation of s_c and p_c as functions of T.

such that it only permits this signal to be overrun in the « stop » position at a speed previously reduced to within the limits imposed.

The minimum distance between two trains will then be (Fig. 5-a_2) :

$$D_p = d_v + d_f + s_p + r \qquad (4)$$

where $d_f = r = 600$ and $d_v = 150$.

If K_p is put $= d_v + d_f + r$, we have :

$$D = s + K;$$

again, keeping $D_p = V \cdot T$, and we have again :

$$s_p = D_p - K_p = V \cdot T - K_p \qquad (5)$$

If the value of cable and equipment necessary for a complete track installation for « intermittent » repetition is put at 20% of that for the stop signal, the equation becomes :

$$p_p = \frac{1 + 0.3 + 0.2}{s_p} . \qquad (6)$$

In figures 8 and 9 are shown curves of variation of s_p and p_p as functions of V and T.

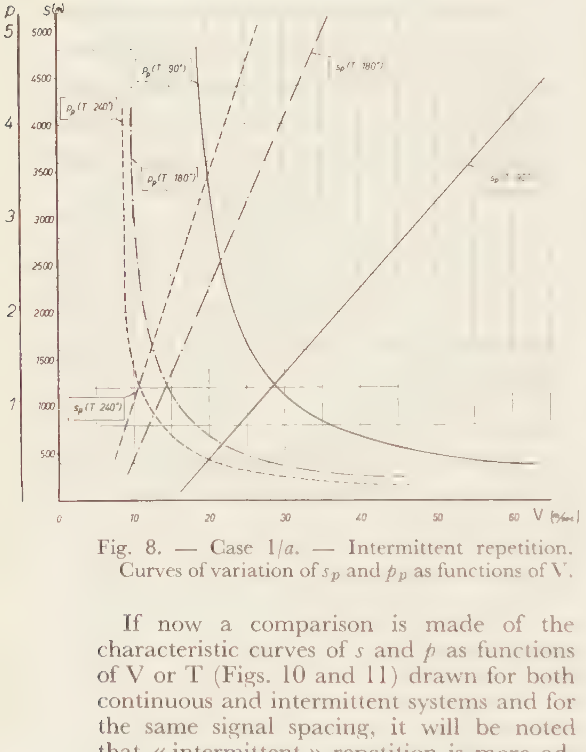

Fig. 8. — Case 1/*a*. — Intermittent repetition. Curves of variation of s_p and p_p as functions of V.

If now a comparison is made of the characteristic curves of s and p as functions of V or T (Figs. 10 and 11) drawn for both continuous and intermittent systems and for the same signal spacing, it will be noted that « intermittent » repetition is more advantageous than the other in the lower part of the diagram : on the other hand, continuous repetition becomes preferable above a certain value of speed V or time T (these values depending on the constants d_v, d_f and r).

As regards line capacity, in fact, the efficiency of the continuous system is inferior to the other so long as the warning repetition is given excessively early, i.e. it is not of an « urgent » character. This difference dis-

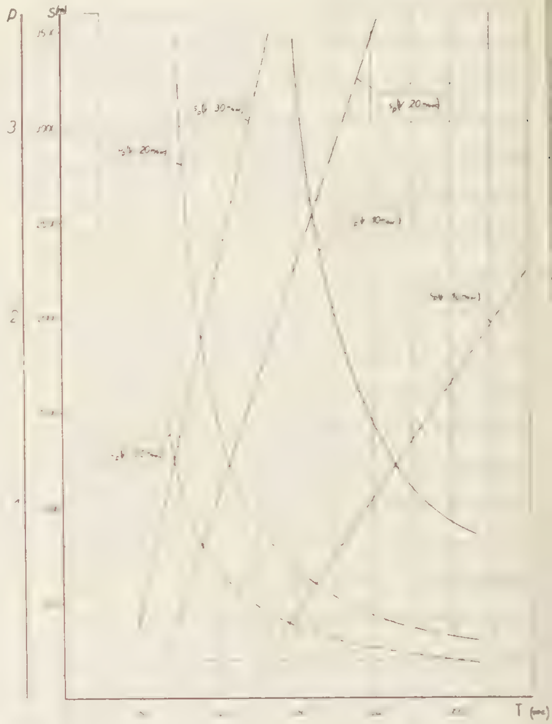

Fig. 9. — Case 1/*a*. — Intermittent repetition. Curves of variation of s_p and p_p as functions of T.

appears when the length of section s_p equals the braking distance (total or partial) d_f (9).

This is brought out by comparing formulae (1) and (4) :

$$d = 2(s - r) \qquad d_v = d_f - s_p - r$$

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(9) The « intermittent » system here appears less attractive economically when $s = d_f$ (the « weight » of signals per km is higher than with continuous repetition) because it has been assumed, for greater simplicity, that the equipment for « intermittent » repetition always has a « weight » equal to 20 per cent of that of a signal location. This assumption is actually not quite valid unless the repeater is installed at a considerable distance from the lineside signal; any reduction of this distance brings with it a similar reduction in lineside cabling and hence in the percentage figure adopted. It should therefore be borne in mind that although the difference between the two systems still exists, it is not so large as is stated.

The diagram figure 12 shows graphs of the variable $(p_c - p_p)$ as a function of T for certain given values of V :

$$p_c - p_p = \frac{(1 + 0.3) \cdot 2}{[VT - (d_v + r)] \cdot 10^{-3}} - \frac{1 + 0.3 + 0.2}{[VT - (d_v + d_f + r)] \cdot 10^{-3}}.$$

With the numerical values adopted, the maximum value of each of these graphs is evidently given by the equation :

$$d\,\frac{(p_c - p_p)}{dT} = 0 = 26 \cdot 10^2 \frac{1}{(VT - 750)^2} \cdot V + 15 \cdot 10^2 \cdot \frac{1}{(VT - 1350)^2} \cdot V.$$

It will be noted that :

(1) the maximum value of $(p_c - p_p)$ remains constant as V varies;

(2) the value of T which produces this maximum value decreases in proportion to the increase of V.

This is because once the constants (r, d_f, d_v) are established the maximum value of $(p_c - p_v)$ corresponds to a well defined value of the distance D = VT between two successive trains.

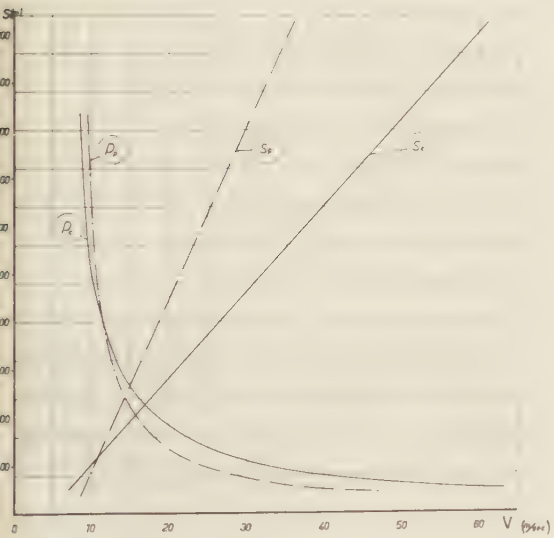

Fig. 10. — Case 1/*a*. — Curves of variation of s_c and p_c (continuous repetition), and s_p and p_p (intermittent repetition) as functions of V for a given value of T (180 sec.).

It has also been considered desirable to compare (Fig. 13) variations of s and p for the continuous and intermittent systems as functions of the value of braking distance for a given train spacing.

As may be seen from the figure, between fairly wide limits of values of d_f, the varia-

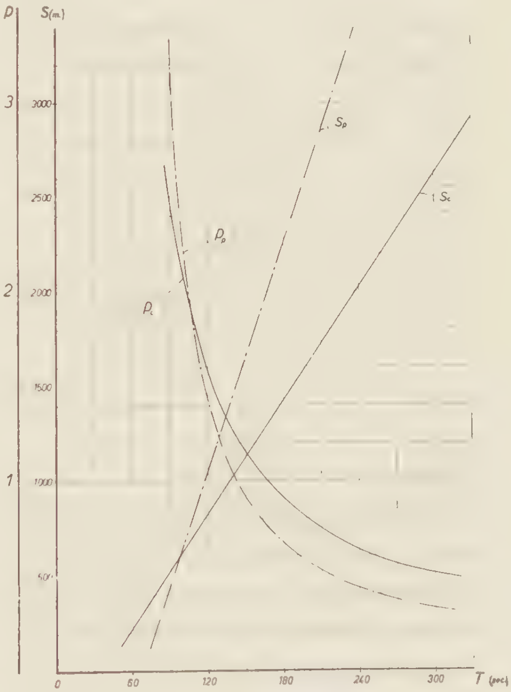

Fig. 11. — Case 1/*a*. — Curves of variation of s_c and p_c (continuous repetition) as functions of T for a given value of V (20 m/sec. = 65.6 ft/sec.).

tions of s_c and p_c are not so sharp as those of s_p and p_p; in particular, it may be noted that the largest differences between these similar values are obtained for the smallest values of d_f.

The addition of an automatic train control system to the track equipment which governs the distance between trains in fact results in an installation capable of new and better performances.

As will be seen more clearly later, the distance between two trains produced by « intermittent » repetition applied to stop signals with associated warning signal is in principle equivalent to that obtained with continuous repetition applied to stop signals with separate warning signal.

Case 1/b. — Stop signals with associated warning signal — with protective section (Fig. 14).

Here also a comparison may be established between two systems as was done previously.

Referring to figure 14-a$_1$, we have :

$$D_c = VT = d_v + 3 s_c;$$

$$s_c = \frac{VT - d_v}{3};$$

$$p_c = \frac{1}{s_c}.$$

Referring to figure 14-a$_2$, we have :

$$D_p = VT = d_v + d_f + 2\, s_p;$$

$$s_p = \frac{VT - (d_v + d_f)}{2};$$

$$p_p = \frac{1 + 0.2}{s_p}.$$

In figure 15 are shown the characteristic curves of s and p plotted against T.

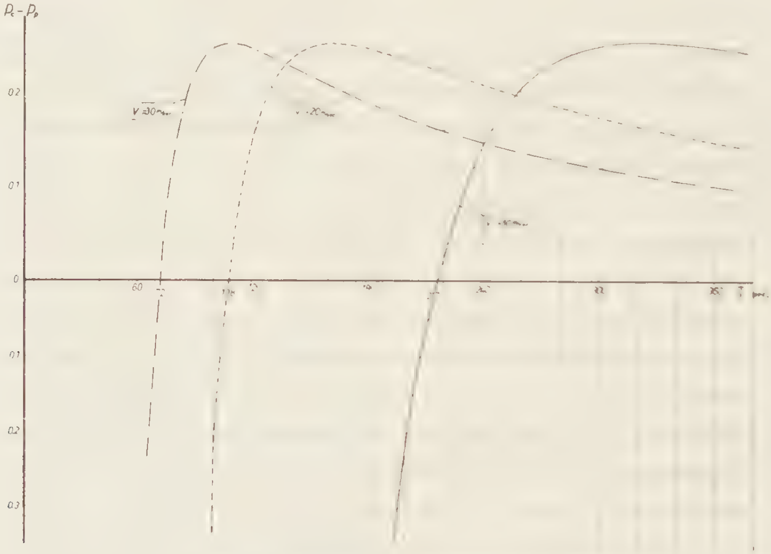

Fig. 12. — Curves of variation of $(p_c - p_p)$ as a function of T.

The slope of the curves is similar to those of figure 11 (sections with protective track circuit) but the limits between which continuous is more advantageous than intermittent repetition are slightly displaced since the arrangement of signals under consideration here is not the same (10).

(10) The scope of this article does not cover definition of the spheres of application of the various types of signal layouts available. It should however be pointed out that the advantage of adopting one rather than another is a function not only of the traffic characteristics but also of the characteristics of the rolling stock employed.

In this case also the two repeating systems have the same efficiency when the length of section is equal to the braking distance.

Case 2/b. — Warning signals separated from stop signals, with protective track circuit (Fig. 16).

From figure 11, for $r = d_f$, it will be seen that :

$$D_{cp} = VT = D_v + 2d_f + s;$$

$$s = VT - (d_v + 2d_f);$$

$$p = \frac{2.3}{s} \qquad (7)$$

In this application, the continuous repetition system provides a prior warning such as may be obtained with the intermittent system; further, in certain given conditions such as the bunching of trains at short distances from each other, it enables a line to acquire a larger « temporary » capacity, as will be seen further on.

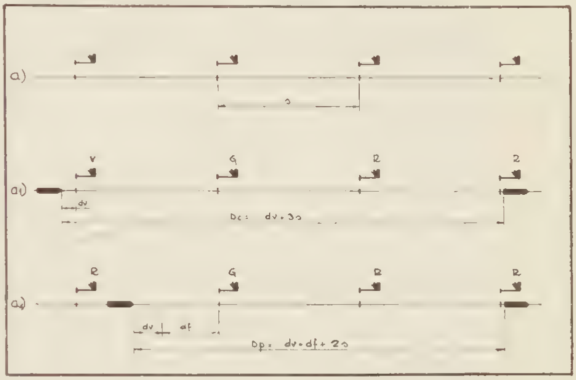

Fig. 14. — Train spacing obtained with lineside stop signals with associated warning signal without protective track circuit but with protective section.

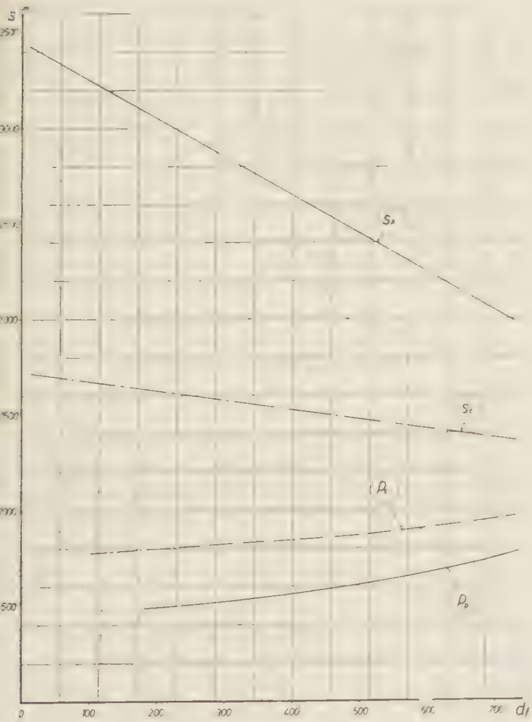

Fig. 13. — Case 1/*a*. — Variation of s_c and p_c (continuous system) and s_p and p_p (intermittent system) as functions of d_f for an assumed value of train spacing of 3 600 m (3 937 yds).

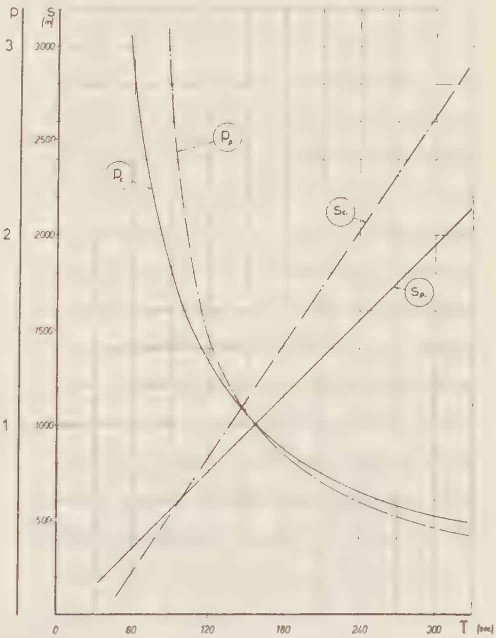

Fig. 15.— Case 1/*b*.— Curves of variation of s_c and p_c (continuous system) and s_p and p_p (intermittent system) as functions of T for V = 20 m/sec. (65.6 ft/sec.).

VI. Influence or repeater type on train spacing for particular traffic conditions.

Consider a length of line AB with any given type of equipment (i.e. with warning signals either combined or separate).

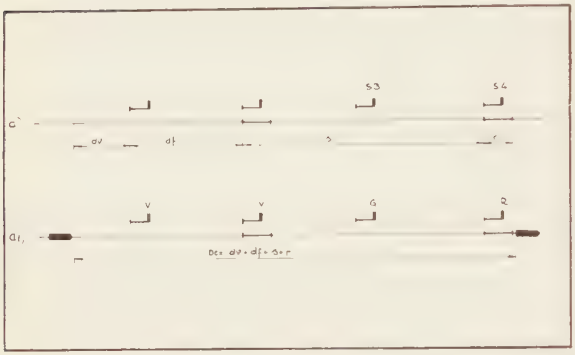

Fig. 16. — Train spacing obtained with lineside stop signals with separate warning signals. Each stop signal has a protective track circuit.

Let it be supposed that on this length signal No. 3 is at « caution » and the following signal No. 4 is at danger in order to effect a booked stop (see e.g. the arrangement in Fig. 16). In this case the two systems give equal performances.

When, however, signal No. 4 is at danger merely because of a chance failure in the signalling installation or in the traffic working it may clear at any moment, which may be during the time that section No. 3 (which will also clear) is still occupied by a train in motion.

Whereas with continuous repetition the running of this latter train may immediately be adapted to the new conditions, with intermittent repetition the running at reduced speed will have to be continued up to the next signal, or at least up to the nearest repeater.

If :

d_f = the length of the « caution » section;

x = the portion of this section already traversed at the moment of change of state of the section;

V_1 = speed under « line clear » conditions;

V_2 = speed under « line clear but section ahead blocked » conditions,

the delay produced by intermittent as compared with continuous repetition will be, as a function of distance (Fig. 16) :

$$T = \frac{d_f - x}{V_2} - \frac{d_f - x}{V_1} = (d_f - x)\left(\frac{1}{V_2} - \frac{1}{V_1}\right).$$

VII. Conclusions.

On the strength of the factors set out above it would appear possible to come to certain conclusions which should be considered as being, if not of general application, at least applicable within the limits of the assumptions made at the beginning of this comparative study, which were :

(1) the possibility of producing an « intermittent » system of repetition with equipment capable of offering a standard of reliability comparable with that offered by equipment for continuous repetition;

(2) the possibility of checking, continuously, at predetermined points the actual presence of track equipment provided for « intermittent » repetition.

On this basis, it is considered that the following conclusions may be drawn :

(*a*) Apart from question of net cost, it appears that the continuous system is clearly preferable when confined to repetition of signals; whereas it appears to impose excessive restrictions on the movement of trains when automatic speed control is added to repetition of the state of the section. In this case intermittent repetition seems preferable.

(*b*) As has been mentioned above, the performance of an installation consisting of stop signals with associated warning signal and intermittent repetition is equivalent to that of a system consisting of stop signals with separate warning signal and continuous repetition; the lower net cost of the former (as established by the relevant values of p obtained from formulae (6) and (7) above) arises from the fact that the « intermittent » repeater may be placed at the required distance from the signal to which it refers without — contrary to what happens with the continuous system — any necessity for the stretch of line between two stop signals to be subdivided into two isolated block sections.

« Intermittent » repetition on lines traversed by rolling stock completely equipped with the necessary vehicle apparatus would make it possible to produce an installation which would regulate train spacing in an even more economical way, and in which all information would be transmitted by an inductive link; stop indications alone being also repeated by the lineside signals.

(*c*) As regards the considerations set out under Section V above, it may be mentioned in passing that the values of V and T which define the limits between which one or other of the systems becomes more advantageous may also vary as functions of the values adopted for d_f and, hence, r. In particular, these limits will decrease directly with decreases of d_f, i.e. in proportion to increases in braking deceleration attainable by the rolling stock running over the line. From present considerations the adoption of the intermittent system might just possibly be advantageous even for lines traversed by trains following each other at close intervals and each possessing high braking deceleration.

(*d*) In comparison with the continuous system intermittent repetition does present a disadvantage when a stop signal is overrun in the danger position. Further information about the state of the section can then only reach the vehicle on passing the next repeater in advance in the direction of running of the train.

After remaining stationary for a certain length of time therefore the train concerned would have to go forward cautiously to the next repeater or to within sighting distance of the next lineside signal.

(*e*) It has been shown in Section VI that under abnormal running conditions the maximum capacity of the line may be achieved with the continuous system.

The efficiency of the « intermittent » system may however be appreciably improved if it is assumed that the reception of the warning signal requires a given response on the vehicle as a sign of vigilance, without controlling the speed of the train.

Taking into consideration that the length of the warning section is limited (since it is not greater than the braking distance) the delay arising from the use of the intermittent system could, in conditions of normal signal visibility, be considerably reduced.

Changes in section conditions would actually be brought to the driver's notice by the signal immediately in advance in the direction of running and this would therefore enable him to regain full speed before reaching the end of the warning section.

[656 .212 .5]

Measuring the speed of humped wagons by means of the continuous high-frequency reflection method for purposes of retarder control, (1)

by Dipl.-Eng. Rudolf WITTING,

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(*Deutsche Eisenbahntechnik*, March 1960.)

1. Introduction.

As part of the present general trend towards a higher degree of automation, shunting techniques also occupy the important place which they deserve. Any efforts in this direction can obviously be of economic interest only in those cases where the additional expenditure is worth while. Experience so far suggests that this is the case with marshalling yards handling about 4 000 wagons per day, or more.

A distinction is made between two types of retarder operation after the wagons have passed over the hump : braking to ensure adequate intervals between cuts, and braking to ensure that the cuts reach their target safely. In either case, efforts have been made for a long time to measure the speed, and these methods have already been employed in certain cases. Earlier methods are generally based on the measurement of the running time over short successive track sections by means of electric rail contacts. It has also been proposed to use optical methods based on the range-finder principle, as well as photo-electric cells, or magnetic and acoustic methods based on the utilisation of the most variegated effects. To-day, however, the methods which appear to offer the best prospects are the reflection methods, the principles and working of which are discussed in the following.

2. Physical and technical potentialities of reflection methods.

2.1. *The principle of « impulse radar » (2) with acoustic and electro-magnetic impulses.*

The term « impulse radar » comprises those methods which measure the propagation time of impulses radiated by an impulse transmitter and subsequently received by an impulse receiver after having been reflected by a suitable object. In order to obtain a continuous measurement of the distance of the object, and the variation in this distance, successive identical impulses are sent out regularly in the form of a « pulsation ». This radar method has become particularly well known from its application during the last war.

For our purpose, it is relevant to assess the results which might be obtained by applying this principle to hump shunting, assuming a judicious rating of the appropriate technical devices.

Consider, as shown in line I of figure 1, a pulsation radiated by a transmitter and intercepted, after its reflection, by a receiver installed at the same place. If the reflecting object is stationary, the pulsation echo is received with a constant time lag τ corresponding to the return trip of the impulses, and is, in principle, identical with the pulsation radiated, though its amplitude will

(1) Paper read at the Third Field-Days of Science of Communications, organised by the Dresden Transport High School and held from the 8th to the 11th June, 1959.

(2) Radar = radio detecting and ranging.

differ. The distance of the reflecting object a can then be calculated from the relation :

$$2a = c(t_{forward} + t_{return}) = c\tau, \text{ hence } \tau = \frac{2a}{c}, \quad (1)$$

where τ is the time lag of the pulsation received compared with the pulsation initially radiated, and where c is the speed of propagation. If, on the other hand, the reflecting object is moving so that its distance decreases, i.e. if the object approaches the radiator and receiver installation, the times $t_{forward}$ and t_{return} decrease continually, and the product $c\tau$ indicates the variable distance. This phenomenon is shown

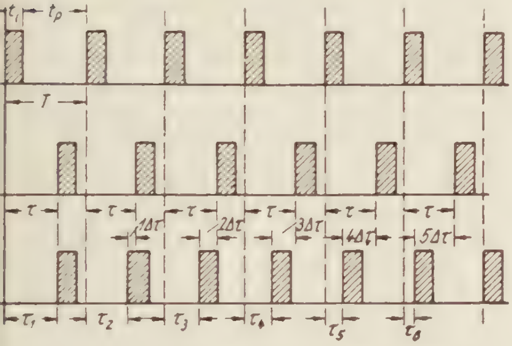

Fig. 1. — Transmitter and receiver impulses.
II with constant distance,
III with decreasing distance.

graphically in figure 1 where line I represents the pulsation radiated, line II the pulsation echo received while a is constant, and line III the pulsation echo received while a decreases at a constant rate. The last impulse on line III obviously represents the condition $a = 0$, as there is no longer any time lag. On the basis of the continually decreasing time lags, it is easy to determine the speed v of the reflecting object if it is kept in mind that the time lag decreases by the difference $\tau_1 - \tau_2$, or, more generally $\tau_n = \tau_{n+1} = \Delta\tau$ if, during the interval T between successive impulses, the distance a is reduced by Δa. Therefore, since $\Delta a = v\mathrm{T}$, the speed of the reflecting object is :

$$v = \frac{\Delta a}{\mathrm{T}}. \quad (2)$$

Moreover, since according to (1) :

$$\Delta a = \frac{c}{2} \cdot \Delta\tau$$

one obtains :

$$v = \frac{1}{2} \cdot \frac{c}{\mathrm{T}} \cdot \Delta\tau = \frac{1}{2} \cdot c\mathrm{F} \cdot \Delta\tau = \text{const} \cdot \Delta\tau, \quad (3)$$

where :

$$\frac{1}{\mathrm{T}} = \mathrm{F}$$

(pulsation frequency).

Without entering into the question of the application of equation (3) from the equipment point of view, we shall try and show how the pulsation must be arranged according to whether one or the other of the two possible types of waves are used : acoustic and electro-magnetic. If a reliable indication is to be obtained, the pulse interval T must at least be so great that it is possible, during that interval, to measure the initial maximum distance, a_{max}. In other words, T must, according to equation (1), correspond to the condition :

$$a_{max} \leq \frac{1}{2} \cdot c\mathrm{T} = \frac{c}{2\mathrm{F}} \text{ or } \mathrm{T} \geq \frac{2a_{max}}{c}. \quad (4)$$

On the other hand, the duration of each impulse t_i is governed by the condition that the minimum time lag τ_{min} at the shortest measuring distance, a_{min}, must still be capable of being perceived or recorded. According to figure 1 and equation (1), it is therefore necessary that :

$$t_i \approx \tau_{min} = \frac{2a_{min}}{c}. \quad (5)$$

To satisfy the condition pertaining at the hump, it is necessary to adhere to the following approximate limit distances :

$$a_{max} = 40 \text{ m}, \quad a_{min} = 2 \text{ m}.$$

One thus obtains a « pulsation ratio » :

$$k = \frac{t_i}{\mathrm{T}} = \frac{a_{min}}{a_{max}} = \frac{1}{20}.$$

With these limiting conditions, one obtains the following two forms of pulsation :

(a) *for acoustic waves,* $c = 340\ m/s$:

$$T \approx \frac{2a_{max}}{c} = \frac{80\text{ m}}{340\text{ m/s}} \approx 0.235\text{ s}$$

$$t_i \approx \frac{2a_{min}}{c} = \frac{4\text{ m}}{340\text{ m/s}} \approx 0.012\text{ s}$$

As the pulsation frequency is :

$$F = \frac{1}{T} \approx 4\text{ c/s}$$

the speed can only be measured about four times per second.

With an initial maximum speed of the humped wagons of $v_{max} \approx 8$ m/s, one thus obtains a « measuring section » of :

$$\Delta a \approx v_{max} \cdot T = 8\text{ m/s} \cdot 0.235\text{ s} \approx 1.9\text{ m}.$$

This section is much too long so that there would be far too few measuring points over the length of the retarder to initiate and carry out a reasonable retardation based on such a crude speed measurement. Acoustic radar is therefore quite unsuitable for this purpose.

(*b*) *for electro-magnetic waves,* $c = 3 \cdot 10^8\ m/s$:

$$T = \frac{80\text{ m}}{3 \cdot 10^8\text{ m/s}} = 0.267\ \mu\text{s};\quad F = 3.75\text{ Mc/s}$$

$$t_i = \frac{4\text{ m}}{3 \cdot 10^8\text{ m/s}} = 0.0133\ \mu\text{s}.$$

In this case, the measuring points are so close to each other that the speed can be said to be measured virtually continuously. On the other hand, the necessary impulse duration, which is of the order of $\frac{1}{100}\ \mu$s, is so small that it would call for important and costly technical apparatus which cannot be economically justified. The numerical example of the hump thus shows that the impulse radar principle cannot be regarded as suitable for our purpose.

2.2. *Non-pulsating (continuous) radar and utilisation of the Doppler effect.*

« Non-pulsating » means « continuous », and in the circumstances, the association of this term with that of « radar » is not very felicitous, though it is commonly encountered. A term such as « method of contionous reflection » would no doubt be preferable. But the term « radar » is so widely used for denoting all the methods of measuring over distances based on the reflection principle that it is proposed also to use it here.

2.21. *The classic acoustic Doppler effect* [1].

There are two forms of Doppler effect. The first arises from the fact that, to a stationary observer, the sound generated by a source of acoustic energy appears to be more high-pitched or more low-pitched according to whether the source is moving nearer to him or moving away from him. The second effect is encountered if the observer himself moves nearer to, or away from, a stationary source of acoustic energy, in which case the frequency observed is again higher or lower, respectively. The two forms of the Doppler effect are characterised by different mathematical relations between the speed of sound propagation, c, and the speed v of the observer or of the source of acoustic energy. It is not proposed to discuss, in this connection, the elementary derivations of these relations. But, if f^* is the Doppler frequency perceived by the observer, and f the frequency of the source of acoustic energy, these formulae can be written as follows :

1. Observer stationary; source of sound moving :

$$f_1^* = f \cdot \frac{1}{1 \;\cdots}$$

[1] It is worth mentioning that DOPPLER (1803-1853) first stated this principle, in 1842, in relation to the deviation towards blue or red of the colours of stars, according to whether a luminous star moves towards us, or away from us. It was only in 1845 that the principle was also applied, by the Frenchman BUYS-BALLOT, to acoustic oscillations.

2. Observer moving; source of sound stationary :

$$f_2^* = f\left(1 \pm \frac{v}{c}\right).$$

In each of these formulas, the upper sign corresponds to the approaching movement and the lower sign to the movement away. As far as the application to hump shunting is concerned, the approaching movement is the only one to be taken into account so that :

$$f_1^* = f \cdot \frac{1}{1 - \frac{v}{c}} \text{ and } f_2^* = f\left(1 + \frac{v}{c}\right).$$

If a wagon running down the hump receives, from the stationary source of sound, waves of the frequency f, the frequency generated at the point of reflection (i.e. at the wagon = « first observer ») is f_2^*. This vibration at frequency f_2^* is reflected towards the source where a pick-up microphone (« second observer ») is installed in the immediate vicinity and thus receives a frequency :

$$f_1^* = f_2^* \cdot \frac{1}{1 - \frac{v}{c}} = f \cdot \frac{1 - \frac{v}{c}}{1 - \frac{v}{c}}.$$

If the maximum speed of the wagon is assumed to be $v_{max} = 8$ m/s, and its minimum speed on leaving the retarder $v_{min} = 2$ m/s, the Doppler factor, for $c = 340$ m/s, becomes :

$$\frac{1 + \frac{v}{c}}{1 - \frac{v}{c}} = \frac{1.025}{0.975} = 1.052 \text{ at the maximum speed,}$$

and :

$$\frac{1.0059}{0.994} = 1.012 \text{ at the minimum speed.}$$

It will thus be seen that, because of the small value of $\frac{v}{c}$, the effect obtained is very small. Even so, it could be used if the source of acoustic energy were to work at a very high frequency, e.g. at ultra-sound frequencies which, because of their very short wave length, are particularly well reflected on the, sometimes rather small, surfaces of the wagons. With e.g., $f = 30$ kc/s, one obtains a wave length of :

$$\lambda = \frac{c}{f} = \frac{340 \text{ m/s}}{30000/\text{s}} \approx 1.1 \text{ cm.}$$

If one uses, in the « receiver », the principle of beat reception which yields as a beat frequency $\Delta f = f_1^* - f$, one obtains, since $\frac{v}{c}$ is very small compared with 1,

$$\Delta f = f_1^* - f = 2f \cdot \frac{v}{c} = 6 \cdot 10^4 \cdot 0.025 = 1500 \text{ c/s}$$

or :

$$= 6 \cdot 10^4 \cdot 0.006 = 360 \text{ c/s}$$

These are audio-frequencies which can easily be amplified and used for the control of switching networks. Against this advantage, however, there is the drawback that there is an unduly long time lag up to the moment when the measurement is actually put to use so that the wagon has, in the meantime, covered a relatively long distance.

2.22. *The electromagnetic analogue.*

The difference, though small in practice, between the two varieties of the acoustic Doppler effect is based on the fact that the medium « air » has been regarded as stationary in relation to radiator or receiver which are also regarded as stationary. In practice, however, if the air is in movement relative to radiator and receiver, other complications arise which, with violent and variable winds, would wholly prevent the use of the system, because of the inaccuracy of the measurements.

In reality, the propagation of electromagnetic waves must be examined with due regard to conditions of relativity, i.e. broadly speaking, without assuming the presence of any stationary medium. Accordingly, as is well known, there can be no signal speed greater than that of light.

Here, again, it is not intended to develop the equations concerned. It may merely be pointed out that, with the electromagnetic Doppler effect, it is quite immaterial whether the radiator or the receiver are moving (in relation to our sense of orientation). All that matters is the relative speed v between the radiator and the receiver. With the same notations as before, the relation applicable to this case is :

$$f_1^* = f_2^* = f \cdot \frac{1 + \frac{v}{c}}{\sqrt{1 - \left(\frac{v}{c}\right)^2}} .$$

As, in this case, the effect is produced twice in succession, viz. first at the reflector, and then at the receiver placed in the immediate vicinity of the radiator, one obtains :

$$f_1^* = f_2^* \cdot \frac{1 + \frac{v}{c}}{\sqrt{1 - \left(\frac{v}{c}\right)^2}} = f \cdot \frac{\left(1 + \frac{v}{c}\right)^2}{1 - \left(\frac{v}{c}\right)^2}$$

$$= f \cdot \frac{1 + \frac{v}{c}}{1 - \frac{v}{c}} .$$

Surprisingly, this result is identical to that obtained with the acoustic effect. As c now signifies the speed of light, $\frac{v}{c}$ is obviously even smaller relative to 1, and it is possible to write :

$$f_1^* = f\left(1 + 2\frac{v}{c}\right).$$

If, also in this case, the principle of beat reception is applied, yielding in the well-known way the difference frequency of f and f_1^*, one obtains :

$$\Delta f = f_1^* - f = 2f \cdot \frac{v}{c} = 2\,\frac{v}{\lambda} ,$$

by making use of the relation :

$$\frac{c}{f} = \lambda .$$

This equation, which may serve as a practical basis for the design of a speed measuring device, naturally applies exclusively to a radial movement of the reflector in the direction of the radiator. If the wagon follows a path passing by the side of the radiator, it is necessary, as shown in figure 2, to introduce the variable cosine of the direction. It is therefore advisable to install the radiator-receiver device between the rails, fitted at a suitably low level.

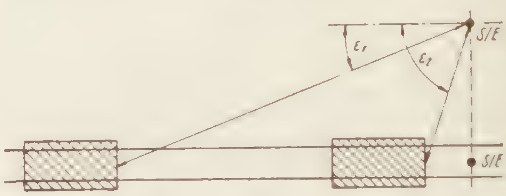

Fig. 2. — Lateral and radial position of the transmitter-receiver equipment.

3. Technical design of the speed measuring device.

A speed measuring scheme must take into account a whole series of data, some of which are governed by physical circumstances, whilst others are influenced by the past development and present state of the retarder technique. To the first category of data belong, first of all, the whole range of speeds from v_{max} to v_{min} as well as the ability of the front end of the humped wagons to reflect the waves. For, in practice, it is necessary to ensure that the very narrow frame of the loading area, at buffer level, is adequate to provide an intensive reflection; this is a horizontal rectangle of about 20 cm height. Even for this reason alone, it is necessary to use very short waves.

The second category of data comprises those parts of the measuring and control installation which govern the operation of the retarder. For the task of the installation as a whole consists in permitting the fully automatic operation of hump shunting; i.e. the automatic application of the correct retardation, both for interval regulation and for reaching the desired target point, from the hump right down to the classification

sidings. Though the different devices required for this purpose are not very extensive, their working is highly complicated so that we shall here confine ourselves to a more detailed description of the high-frequency part of it.

3.1. *The most favourable high-frequency band.*

For reflection purposes, it is necessary to use a wavelength which is much shorter than the smallest dimension of the reflector. It is therefore immediately apparent that centimetre waves are the only ones that can be used. On the other hand, the Doppler difference frequencies Δf produced, which serve as a criterion for the wagon speeds, are also of some importance. The difference frequency must neither be too low nor too high so that it can be conveniently amplified and processed. The relationships are illustrated in figure 3.

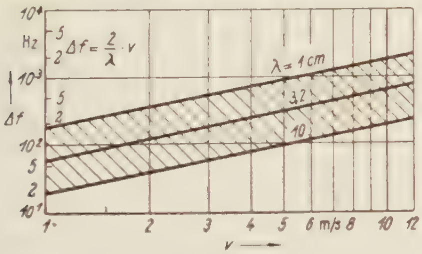

Fig. 3. — Doppler difference frequency Δf as a function of the speed v of the reflector.

It will be seen that, with $\lambda = 10$ cm, one obtains difference frequencies ranging, approximately, between $\Delta f = 20$ and 200 c/s, assuming a minimum speed of $v_{min} = 1$ m/s and a maximum speed of $v_{max} = 10$ m/s. For $\lambda = 1$ cm, one correspondingly obtains $\Delta f = 200$ to 2 000 c/s. All these frequencies are in the lower audio-frequency range and can easily be amplified and used for the further circuiting although, generally speaking, the frequencies below 200 c/s are less suitable because of the interference frequency spectrum which is always present in this range. For this reason, the high-frequency type speed measuring devices hitherto known have been equipped, for railway purposes, i.e., for the low humping speeds encountered, with transmitter-receiver apparatus working on a wavelength of approx. 3 cm. Even better suited would be waves of the millimetre range, but these are at present still giving rise to difficulties with the valve generators and mixer valves. Since only a « monochromatic » wave radiation can be used, one might conceivably select, e.g. a « line » from the gas discharge spectrum where the wavelength is largely independent of external operating conditions. Because of the simultaneous action of daylight or artificial light, and the always present heat radiation, one might for instance use an ultraviolet line filtered out from the mercury vapour spectrum, though the question of a technically practicable mixer stage or an equivalent processing system has not yet been solved. With these wavelengths, it would also be necessary, first of all, to examine whether the ability of the wagons to reflect the waves and the presumably strong absorption encountered during fog, etc., are in keeping with the specifications. For the time being, therefore, the short-wave centimetre band remains the most favourable high-frequency range.

3.2 *The high-frequency part.*

On the strength of the principles just discussed, the high-frequency part of the speed measuring device can be represented in the form shown in figure 4. The wagon rolling down from the hump approaches the retarder at an initially increasing speed v, and the radiator-receiver device produces a corresponding difference frequency Δf. The wagon is then slowed down as it enters the retarder. As soon as a certain most favourable wagon speed is attained, which can be pre-calculated from the weight and rollability of the wagon, from the distance to be covered, and from other influences, the braking effect of the retarder jaws is reduced, and finally relaxed when the wagon has attained the release speed required to reach its point of destination. As simple as this description may appear to be at first glance, it nevertheless presents important problems of technical realisation, and calls for rather

expensive computing devices which cannot be discussed within the framework of the present paper. The high-frequency part of the installation, required for determining the speed, is schematically represented in figure 5. There are the two antennae for transmission and reception, the transmitter generator, the receiver and mixer diode with the amplifier unit connected to it, and the amplitude limiter which has the effect of ensuring that, in spite of the changing reflection conditions, a suitably chosen constant output voltage of the Doppler difference frequency Δf is always available. The absolute constancy of this output voltage at audio-frequency is essential, for the following reason.

Any electric control operation must be expressable in the form of an amplitude. In this case, however, the primary control variable v is converted into a difference frequency Δf proportional to it. The latter variable must thus be used exclusively, and any other characteristic of the control variable must therefore remain ineffective; in other words, for an alternating voltage, $|u|$ = constant. (As far as the oscillation phase is concerned, which represents the third determinant, there is no need to comply with any special conditions as long as the evaluation system is indifferent to it.)

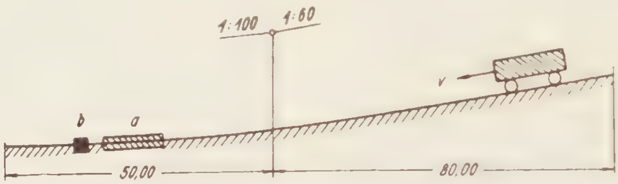

Fig. 4. — Gravity hump with retarder and transmitter-receiver equipment.

a = Retarder; b = Transmitter-receiver unit.

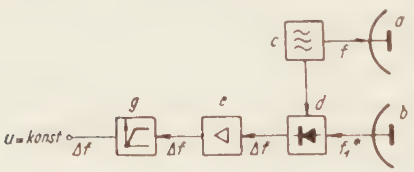

Fig. 5. — High-frequency unit of speed measuring device.

a = transmitter antenna,
b = receiver antenna,
c = transmitter generator (klystron, λ = 3 cm),
d = receiver and mixer diode,
e = amplifier for the difference frequency, Δf,
f = frequency,
g = amplitude limiter for constant output voltage.

Another possible solution, which does not require an amplitude limiter, consists in using the amplified audio-frequency voltage $u(\Delta f)$, the amplitude of which must attain a value of at least several volts at the amplifier outlet, for the control of a phantastron which, in its turn, supplies an impulse voltage of constant amplitude, the frequency of which is exactly synchronized with Δf.

It may here be pointed out that the two methods just described are at present being tried out in the Soviet Union; the first at Leningrad, the other in Moscow.

Different solutions may also be adopted as regards the arrangement of the antennae. If, as shown in figure 6, only one antenna is used, it is necessary to ensure that the relatively high transmission energy does not reach the receiver and mixer diode in its full strength as the latter would otherwise be rendered useless for its task. It is therefore necessary to use a very effective but adjustable decoupling device between the transmitter circuit and the receiver circuit. This may be achieved, for example, in the following way.

One makes use of a « ring circuit » of a

total length of $L = \frac{3}{2}\lambda$. One of its semi-circles remains continuous between points x_1 and x_4, whilst the other semi-circle is divided, by means of two tappings x_2 and x_3, into three sections, each having a length of $\frac{\lambda}{4}$. As will be seen from the diagram, the « receiver » d is disconnected from the transmitter c because the sections of line between them have a length of $2 \cdot \frac{\lambda}{4}$ and $4 \cdot \frac{\lambda}{4}$, respectively, thus differing from each other by the value $\frac{\lambda}{2}$, so that they act in phase opposition, i.e. remain ineffective, at the connection point of d, x_3. On the other hand,

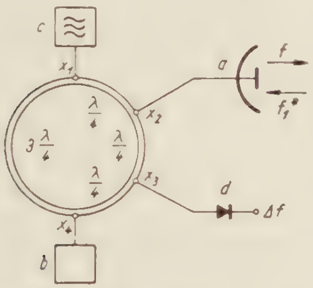

Fig. 6. — Ring circuit ensuring the decoupling of transmitter and receiver.

a = joint antenna,
b = antenna equilibrator,
c = transmitter,
d = mixer diode.

there are, at this point, introduced voltages received by the antenna acting as receiver organ. For, the sections of line between points x_2 and x_3 have a length of $1 \cdot \frac{\lambda}{4}$ and $5 \cdot \frac{\lambda}{4}$, respectively, so that they supply co-phasal voltages. The equilibration of the antenna resistance at the envisaged point x_4 is necessary so that a kind of « bridge equilibrium » is obtained. But it is necessary to resign oneself to the fact that only one-half of the transmitting energy is transmitted to the antenna, and moreover, that only one-half of the energy received can be introduced into the mixing circuit. In practice, however, there is always, due to the circuit design, a residual coupling between c and d which, as experience shows, corresponds to a power ratio of approx. 1 in 1 000, and is just sufficient to ensure a favourable mixture of f and f_1*.

A similar mode of operation can be obtained with the aid of the « direct connector » known in wave guide technique under the name « magic T » which, in the same way as a symmetric bridge circuit, supplies a decoupled « neutral branch ».

The technical realisation of the high-frequency unit is relatively simple. In general, the ultra-high frequency generator used for this purpose is an electronically stabilized klystron which supplies a few hundredths of a watt, i.e. a relatively low power. From an energy consumption point of view, the method of reflection of centimetre waves is thus very economic, even if its overall electric efficiency is very low.

3.3. *The low-frequency unit.*

The low-frequency unit connected to the high-frequency unit has the task of transforming the constant voltage of the frequency Δf into a voltage amplitude which is exactly proportional to it, and which is subsequently used as a control variable v, « wagon speed ».

By differentiation, one can obtain the deceleration $b = dv/dt$. This operation, which can be carried out electrically without difficulty, offers the possibility of reducing the brake pressure when a deceleration determined by practical experience has been reached, i.e. initiating a relaxation of the retarder and thus maintaining, in a more precise manner, the desired release speed of the wagon. This function is controlled not only by the variable Δf but also by the result obtained by the computer which is influenced by other variables such as the rollability of the wagons, the track layout, the degree of track occupation in

the classification sidings, weather conditions, etc. This low-frequency unit is housed in a service building so that, in contrast to the transmitter-receiver equipment, it need not be weatherproof.

4. Conclusions.

The preceding discussion indicates the importance of the investments required to set up such an installation and to maintain it in good working condition. Inspection and maintenance of the equipment, recalibration, and the checking of the proper co-ordination of the different parts call, from time to time, for the attention of trained and skilled staff. From an economic point of view, it is therefore necessary to examine to what extent the efficiency of major marshalling yards can still be enhanced by such automatic installations, and for how long these must be used before the capital cost can be retrieved.

On the other hand, it is necessary to take into account that a large marshalling yard without automatic installation calls for the employment of numerous wagon chasers in several shifts throughout the day and night. These men have to carry out, in all kinds of weather, a difficult and dangerous job which they can only perform under conditions of very high physical fitness. Due to the need for uninterrupted intense concentration and for split-second reactions, these men are veritable heroes of work. Our aim should therefore be to direct them to a more agreeable and more rewarding job. For, what has been achieved in this respect in modern workshops of the large production enterprises is even more appropriate to outdoor work on the railways.

Summary.

A description is given of the physical and technical potentialities of the reflection methods as well as the technical principles of the speed measuring installations suitable for use in marshalling yards. It is found that the best solution available at present is provided by the use of non-pulsating electromagnetic radar based on the double Doppler effect. Such installations are already being tried out in several countries and have, in some cases, already been in successful operation for a fairly long time. They only represent a very small part of a complete automatic shunting installation. The latter also comprises measuring devices for the determination of all the other independent variables which must be fed in the form of electric data into an electric computer, e.g. one designed to calculate the distance to be covered by the wagon.

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New electric multiple-units for British Railways.

(*Trains Illustrated*, November, 1960.)

To provide 25 kV A.C. electric services between Manchester and Crewe, over former North British lines in the Glasgow area, and between Liverpool Street and Bishops Stortford, Hertford East, Enfield and Chingford, British Railways have placed in service or have on order 207 electric multiple-units. This total includes units already under construction for extensions of 25 kV A.C. electrification British Railways expect to complete in the next year or so, but is additional to the 112 units already delivered for the London Tilbury & Southend electrification. These 112 units have been used so far for testing and crew-training on the Manchester and Clacton lines and were described in the June, 1959, issue.

The electrification schemes vary considerably in the type of traffic, the physical characteristics of the lines involved and their economical scheduled speeds. Nevertheless, basic performance requirements have been standardised and include a maximum speed of 75 m.p.h. with half-worn wheels and an acceleration rate of 1.1 m.p.h.p.s. for a four-car unit, or 1.35 m.p.h.p.s. for a three-car unit. All the units are equipped to work on either 25 or 6.25 kV A.C.

Coach body construction follows the usual B.R. practice with 16-gauge steel sheets welded to angle-section pillars and rails; the sides, ends and roof are individually manufactured in jigs and later welded to the vehicle underframe. All vehicles are mounted on the B.R. standard 63 ft. 5 in. underframe and run on Gresley-type double-bolster bogies. Practically all the electrical equipment is suspended from the underframe; the exceptions are the pantograph, circuit breaker and voltage detector, all of which are mounted on the flattened portion of the roof over the guard's compartment in each motor coach. Buckeye couplers are fitted throughout each unit.

With the exception of the Glasgow stock, the coaches are built to the standard B.R. « C 1 » profile, 9 ft. wide over body at waist and 9 ft. 3 in. overall, with side swing doors to each seating bay or compartment. The body length varies between 63 ft. 6 in., in the case of flat-ended intermediate coaches, to approximately 64 ft. over the bowed outer ends of driving coaches. The Glasgow stock has sliding doors and the coach bodies are built to the maximum permitted overall width of 9 ft. 3 in.; this extra three inches at the coach waist affords more room internally at seat level. To ensure that the maximum width is not exceeded the driver's and guard's swing doors and grab handles are slightly recessed in the bodyside. Cavities in the coach bodysides, ends and roofs are filled with insulating material, such as Fibreglass or sprayed asbestos, to ensure adequate sound and heat insulation.

The standard driver's controls comprise a reversing handle giving forward, off and reverse positions and a master controller, incorporating a dead man's action, with four positions — shunt; half voltage; full voltage; and weak field. All units have Westinghouse electro-pneumatic and automatic air brakes. The driver's brake valve has seven positions — running; variable self-lapping electro-pneumatic leading to full e.p. application; Westinghouse air brake lap; Westinghouse air brake service application; emergency application; and neutral.

Electrical equipment.

Current is taken from the overhead contact wire at 25 kV or 6.25 kV by one Stone-Faiveley pantograph, and is passed to the

(British Railways.)

Top: Glasgow suburban, Scottish Region.
Below: Liverpool Street-Enfield and Chingford, Eastern Region.

main circuit breaker and the voltage detector apparatus. An earthing switch is also incorporated in the H.T. circuit to afford protection to men working on any part of the train's electrical apparatus.

The primary winding of the main transformers is in four sections, which are fed in series for 25 kV operation or parallel for 6.25 kV supply; an electro-pneumatic voltage changeover switch mounted in the

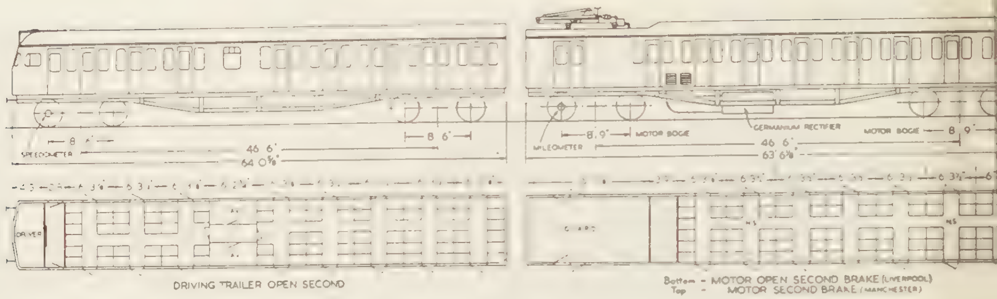
transformer housing is operated by the voltage detector and A.P.C. (Automatic Power Control) circuits. The current, now transformed to relatively low voltage A.C., passes to the control equipment through transformer tappings on the secondary winding and into the main rectifier. Here, although the essential function of the control equipment is identical, the detail control methods vary between the three types of stock in association with the type of rectifier in use. L.T. tap-changing has been employed in all units since it is inconvenient to use H.T. tap changing and current load on the secondary winding is not high enough to cause switching problems.

(British Railways.)

Manchester-Crewe, London Midland Region.

The method of voltage detection at changeover points and the automatic setting of the transformer to either 25 kV or 6.25 kV has been standardised both on the A.C. locomotives and also on multiple-units. (Incidentally, there are no 6.25 kV sections on the first portion of electrified L.M. main line between Manchester and Crewe.) Where changes in phase or voltage occur, neutral sections are introduced in the overhead line consisting of three successive short sections of wire, insulated from earth but not energised. To avoid damage to the overhead wire and pantographs when a neutral section is entered, automatic power control, utilising lineside permanent-magnet inductors of A.W.S. type in conjunction with bogie-mounted receivers on the traction units, opens the circuit-breaker before the pantograph reaches the dead section of overhead line; after it has left the neutral section, the circuit-breaker is automatically released and closes under the control of the voltage selection equipment. This automatic safety precaution is standardised to enable a multiple-unit train to negotiate neutral sections without the motorman shutting off, since it is considered impracticable to expect him to do so, even though it might reasonably be expected of a locomotive driver.

The Glasgow units, for which Metropolitan-Vickers (now part of A.E.I.) supplied the equipment, employ four single-anode, pumpless, steel tank, air-cooled mercury-arc rectifiers supplied from seven transformer tappings, with additional transition resistors connected in series with a transformer tap on alternate notches to give intermediate voltages. The four rectifiers are bridge-



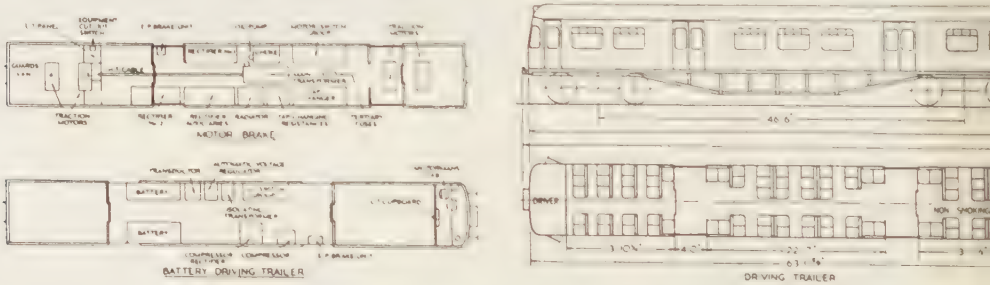
Layout of a Crewe-Manche

connected and supply the four D.C. traction motors on a permanent series-parallel circuit. The electrical equipment supplied by G.E.C. for Bishops Stortford/Hertford and Enfield/Chingford units comprises eight Compak single-anode mercury-arc rectifiers arranged in two bridge circuits, each feeding two traction motors in series. Nine transformer taps with two contacts per tap, one feeding a series resistance, and additional motor field weakening steps, give 20 notches.

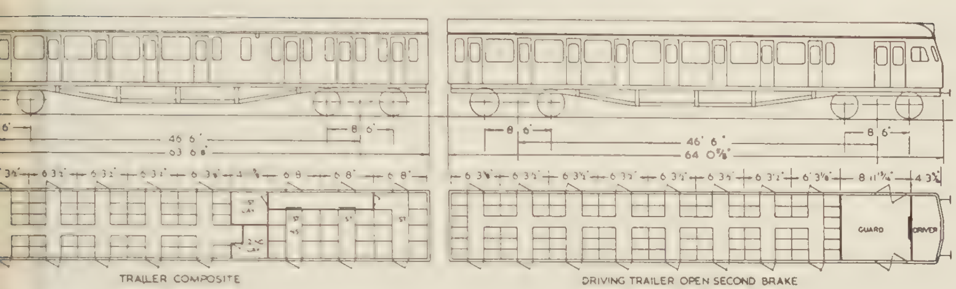
On the other hand, the Crewe/Manchester/Liverpool units, for which British Thomson-Houston (also now part of A.E.I.) were the electrical contractors, have germanium rectifiers, the first production order for this type of equipment on British Railways' multiple-units. The advantages of these semi-conductor rectifiers over the mercury-arc rectifiers lie in their reduced size and weight, their simplicity and the avoidance of heaters to ensure satisfactory operating temperatures for the mercury-arc type. However, adequate air-cooling is vital for the satisfactory function of germanium rectifiers. The traction current supply is increased by a buck-boost system of control through opposed transformer windings in which the voltage is stepped up in 17 steps from 5 transformer taps in conjunction with a tap-changing reactor.

The axle-hung, nose-suspended D.C. traction motors are virtually identical with conventional D.C. motors, but because they have been designed to operate on a rectified A.C. supply, they are slightly larger and heavier and incorporate detail circuit modifications. The operating voltage and horse-power vary slightly between units because of the detail differences in the control system and rectifiers.

To complete the circuit of the transformer primary winding an earth connection is taken from the transformer to brushes mounted on the motor coach axles. The



Layout of a Glasgow suburban three-car unit, showing o



ol four-car unit.

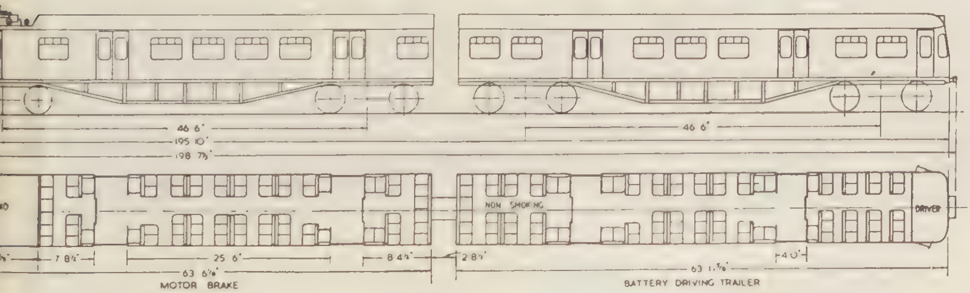
normal ratings of the units are based on a line voltage of 22.5 kV or 5.625 kV.

In addition to the transformer secondary winding for the traction supply, a tertiary winding at 240 V supplies A.C. to various auxiliary machines, such as the rectifier cooling fan or coolant pump, transformer circulating oil pump, coach heaters and, through a bridge rectifier, the main compressor. Other auxiliaries, such as coach lighting, control circuits, electropneumatic brake supply and the auxiliary compressor, all of which are required to function independently of the high voltage supply, are fed from the unit's batteries on a 110 V D.C. circuit; the batteries are charged from an A.C.-driven battery charger.

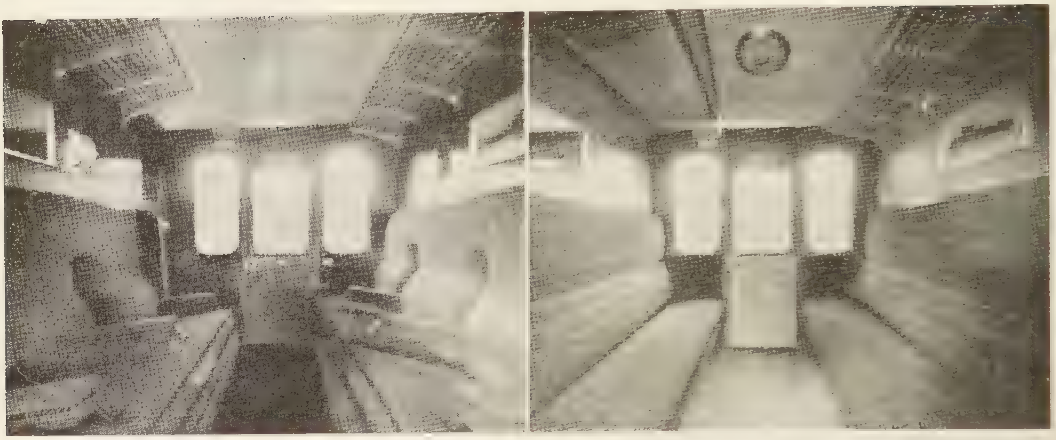
In addition to the new units, the existing Liverpool Street-Shenfield/Chelmsford/Southend stock built in 1949 and 1956 for the 1 500 V D.C. system is being converted as these lines have been altered for 25 kV A.C. operation coincidentally with the Bishops Stortford and Enfield electrifications. New pantographs and transformers supply germanium rectifiers similar to those employed on the Manchester-Crewe sets. The maximum traction voltage of 1 500 V D.C., however, is being retained although modifications to some auxiliary circuits and the driver's controls will ensure that these units are identical in all other important respects with the new 25 kV A.C. stock.

Manchester/Liverpool and Crewe.

The varied operating requirements of the new electrified lines naturally dictate differences on formation and internal layout. The two batches of 15 sets for Manchester and 20 sets for Liverpool, built at Wolverton works, L.M.R., are basically similar. Each unit is formed of a driving trailer open second (with toilet compartments), non-driving motor brake second (open in



left the arrangement of the electrical equipment.



First and second class compartments of a Manchester-Crewe unit.

the Liverpool units), trailer composite (with toilets) and driving trailer open brake second, but the outcome of policy and design changes during production is that there are considerable detail variations between the two batches, notably in the window design and in internal decor. The internal layout of the motor coach differs too: it is arranged with eight compartments in the Manchester sets and as a seven-bay saloon, with correspondingly larger guard's compartment, in the Liverpool sets. The latter units, therefore, have all their second-class accommodation in open saloons. The

(British Railways.)

Top: A composite trailer of a Manchester-Crewe unit.
Below: A motor brake second of a Manchester-Crewe unit.

first class accommodation is in three compartments connected by side corridor to a toilet compartment. The Liverpool sets have one large window 3 ft. 5 1/2 in. wide between each two doors in the open saloons, instead of the hitherto standard quarterlights used in the Manchester units.

A new method of fitting the windows has been employed on the Liverpool sets (and, incidentally, on miniature buffets and open second coaches now being built at Wolverton). The window comprises a separate aluminium frame screwed to the coach body from the outside, a reversion to a practice employed widely in past construction of wooden bodied coaches and of some Southern Railway steel-panelled stock. The advantage of this is that replacement is possible by removing the whole frame without disturbing the interior of the window surround and adjacent fittings. The Manchester units also have separate window frames but these are attached to the inside in the normal way.

The side doors are constructed from an aluminium casting and a new development here is the use of a timber facing inside instead of the more usual aluminium sheet. The frameless droplights are fitted with an improved Beclewat opening catch, which is easier to operate than earlier designs. Fibreglass mouldings form the domed roof at the driving ends and the drop roof of the motor coach, which joins the elliptical section of the flattened portion under the pantograph.

Heating is by 500 W. G.E.C. heaters under each seat, thermostatically controlled, with general control by the guard. The Gresley type bogies are equipped with Timken or Skefco roller-bearing axleboxes.

As to internal decor, the bright finish of the Manchester units is in strong contrast to the sombre style of the Liverpool sets. In the Manchester sets, bodysides panelled with walnut veneer are matched with end partitions in Warerite yellow, door panels of Warerite stardust blue and second class seats upholstered in dark green uncut moquette. The linoleum is of pigeon-grey marble design. The first class compartments are finished entirely in walnut (except for the ceilings), with blue/black moquette and a charcoal-and-gold patterned carpet.

The Liverpool unit bodysides are also finished in veneer — crown elm in the second class saloons and Indian silver greywood in the firsts. The plastic end panels, however, are an unimaginative pearl grey

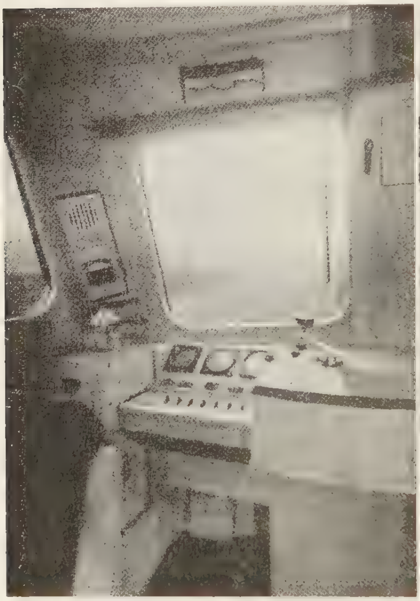

Open second class saloons of a Glasgow suburban unit (left) and a Manchester-Crewe unit (right).

and, combined with charcoal lino and the same dark-green upholstery as in the Manchester sets, the effect is drab.

Glasgow suburban.

The most striking feature of the electric units built by Pressed Steel for the Glasgow suburban electrification is the complete break-away from the traditional side-door designs standardised for all British Railways' suburban trains so far. The saloon layout combined with sliding doors, used here for the first time on a British Railways design, is by no means new, however, and the new Glasgow stock resembles in several respects the L.M.S. stock built in 1939 for the Liverpool-Southport line.

The new streamlined front end design, virtually identical with the new « standard » Diesel train front end seen for the first time on the Swindon-built Hull-Liverpool « Inter-City » sets, is a considerable improvement over earlier types. An important feature here is the provision of a glass partition between the passenger saloon and driver's compartment allowing passengers a forward view, a popular selling-point of Diesel trains but inexplicably absent on electric trains until now.



(British Railways.)
A new driving control desk layout designed for the Manchester-Crewe multiple-units.

(G. E. C.)
The interior of an open saloon in an Eastern Region three-car unit for the Great Eastern Line. Note the fluorescent lighting.

The three-car sets, which are second class only, are formed of a non-driving motor coach, including a guard's compartment, sandwiched between two driving trailers, one of which carries the unit's batteries. Internally, the coach walls and doors are faced with Formica plastic panels of decorative blue and grey, with polished African walnut timber surrounds to the vestibule partitions. Seats are covered in patterned moquette, in various colour schemes. The

The new multiple-units : leading particulars.

	Glasgow			Liverpool/Manchester/Crewe				
	DTSO Batt.	Motor BSO	DTSO	DTSL Batt.	MBS Manchr.	MBSO Livpl.	CL	DTBSO
Length over body	63′ 11 5/8″	63′ 6 1/8″	63′ 11 1/8″	64′ 0 5/8″	63′ 6 1/8″	63′ 6 1/8″	63′ 6 1/8″	64′ 0 5/8″
Weight	37t 9 1/2c	55t 11 1/2c	33t 17 1/2c	35t 12 1/2c	53t 17c	53t 17c	31t 5 1/2c	31t 8c
Seats 1st	—	—	—	—	—	—	19	—
Seats 2nd	83	70	83	80	96	72	60	82
Traction motor voltage	—	975	—	—	975	975	—	—
Continuous rating of motors (weak field)	—	210 HP	—	—	207 HP	207 HP	—	—
Equipment	—	MV(AEI)	—	—	BTH(AEI)		—	—
Type of rectifier	—	M.Arc	—	—	Germanium		—	—

	Enfield/Chingford			Bishops Stortford/Hertford East			
	DTSO Batt.	MBSO	DTSO	DTSLO Batt.	MBS	CL	DTS
Length over body	63′ 11 1/2″	63′ 6″	63′ 11 1/2″	63′ 11 1/2″	63′ 6″	63′ 6″	63′ 11 1/2″
Weight	34t 1c	54t 4c	30t 16c	35t 18c	54t 18c	31t 0c	32t 4c
Seats 1st	—	—	—	—	—	19	—
Seats 2nd	94	84	94	80	96	60	108
Continuous rating of motors (weak field)	—	200 HP	—	—	200 HP	—	—
Equipment	—	GEC	—	—	GEC	—	—
Type of rectifier	—	M.Arc	—	—	M.Arc	—	—

units have transverse seats, two and three astride the passageway with single or double longitudinal seats alongside the two entrance vestibules in each car.

Great Eastern suburban.

The stock for the suburban electric services from Liverpool Street to Hertford East, Bishops Stortford, Chingford and Enfield to be introduced on November 21 and built in British Railways' works at York and Doncaster, comprises two types of unit : four-car outer suburban sets including first class and toilet accommodation; and three-car inner suburban, second class only sets. The four-car units are formed of a battery driving trailer, lavatory open second, non-driving motor brake second, trailer lavatory composite (with second class accommodation open), and driving trailer second; in general layout they conform to the existing four-car A.C. units for the London, Tilbury and Southend line. The three-car units for the Enfield and Chingford lines are formed of a battery driving trailer second, non-driving motor brake second and driving trailer second, all with saloon accommodation. The front end design of both types of unit is identical to that employed on the Manchester-Crewe stock. Large side windows in the Enfield/Chingford sets and the use of low-back seats as in the Liverpool-Crewe sets combine to give passengers a good view, but unfortunately no forward prospect through the driver's cab. The interior decor of both types of unit has been specified by the B.T.C. Design Panel; plastic-faced panels and wood veneers set off the decorative moquette seating.

[656 .232 (44)]

Costing on the French National Railways,

by Raymond LARTIGUE.

(*Annales Suisses d'Economie des Transports*, No. 3, 1960.)

I. GENERAL

The railway is not an industry with a given production : it assures many extremely varied services and the problem of costing its transport is extremely complex.

The total passenger and goods traffic of the French National Railways Company (S.N.C.F.) represents every year hundreds of millions of transport jobs each of which has a dinstinct cost price, corresponding to different combinations of a great many variants. Amongst these we may mention :

— the transport distance;
— the method of traction (steam, electric, diesel);
— type of rolling stock used;
— coefficient of user of the rolling stock;
— the coefficient of unbalance of the traffic;
— the importance of peak traffic;
— the profile of the lines used.

The object of costing railway transport is to determine the expenses of each category, sub-category or traffic operation, as well as that of the various operating requirements.

The calculations are generally concerned with existing traffic, but may also bear on new traffic.

The application of classic methods of costing used in industry would involve very considerable administrative and accountancy work, so that it appeared preferable to perfect some particular methods designed specially for the railway to determine both *the average general cost* and *the particular or individual costs*.

The activities of the railway as a manufacturer of spare parts and repairer of stock also require calculations of the cost, but these latter can be carried out on the lines currently used in industry, and will not be dealt with in the present article.

The difficulty of calculating the transport costs on the one hand and the monopoly in fact which the railways enjoyed on the other hand led them to neglect calculating their costs for a long time.

The first large scale studies in this field were carried out soon after the first world war in the United States and Germany.

In the *United States* a complete method of costing was perfected by a section of the Research Office of the Interstate Commerce Commission (I.C.C.) (1).

These calculations rested on two important bases :

— a very detailed accountancy plan which allowed of a complete and detailed classification of the expenses,
— a statistical plan,

the application of which was made obligatory by the I.C.C. on all Class I railways (annual receipts exceeding 1 000 000 dollars).

As a first stage, rules for allocating the expenditures of an exclusively accountancy character were laid down by the I.C.C.; it then studied the problems of the extremely arduous industrial analysis involved in calculating individual costs.

The distinction between fixed costs and variable costs made it possible to determine simultaneously the marginal costs and total costs, as well as studying the influence of the different factors on variations in the costs.

(1) See the review « Transports », January 1959.

It is already more than thirty years since the *German Railways* began regularly to divide up their costs for each working year between the different services.

Very detailed instructions give the methods to be used :

— on the one hand, for calculating the general average costs, known by the abbreviation « Beko »,

— and on the other hand, for calculating the cost of running a train, known as « Zuko ».

The use of graphs consisting of a series of curves made it possible to simplify the work carried out to begin with from complex formulae with a large number of parameters.

The diagrammatic map of the system known as the « Pfennigkarte » which is prepared each year, which to start with gave the cost per gross ton-km per section of line and per category of train, has been replaced by « Comparative maps of operating costs of through goods trains ».

The Convention of the 31st August 1937, concerning the constitution of the S.N.C.F., making it obligatory for them to divide up their costs between the different categories of traffic, meant that calculating the costs was one of the first problems which the S.N.C.F. had to try and solve.

The study was confided to the Technical Department of the General Management, which has since become the General Studies Management, which under the leadership of its eminent Manager René DUGAS prepared a method of calculating the average costs, which was applied for the first time to the results of the year 1938.

This method, after having undergone various successive improvements, was used to carry out general studies of the costs in 1948 and 1954; a new study is in hand at the present time, which will deal with the results of the year 1959.

In 1946, the Management Committee of the *U.I.C.* decided to entrust to a special Sub-Commission of the IIIrd Commission, the elaboration of a method of costing railway transport.

This Sub-Commission, under the Chairmanship of the Netherlands to begin with and later on of France (1), carried out the important work which led to the publication of a series of advisory leaflets.

Amongst those dealing directly with railway transport costing, mention may be made of :

— Leaflet 374 : Principles to be observed in calculating the general average costs and special costs;

— Leaflet 375 : Transport costs for full wagon loads. Study of the laws of variation of these costs;

— Leaflet 376 : Cost of sundries goods traffic. Study of the laws of variation of these costs;

— Leaflet 378 : Application of the costing of passenger traffic in studying the laws of variation of these costs.

The development of competition from other methods of transport has made it more and more necessary to fix tariffs based on the costs, so that nearly all the Railway Administrations of Western Europe have been led to carrying out costings based on the methods recommended by the *U.I.C.*

The *Belgian National Railways Company* has carried out costings for some twenty years; like the S.N.C.F., they use a method very similar to that of the U.I.C.

The *Swedish Railways* have also studied very closely the problem of costs. The dividing up of the costs does not seem to them to be of great value, as well as calculation of the average costs, and it seems to them more useful to calculate the particular costs relating either to a given transport or to one group of traffic.

The *Netherlands Railways* who, as soon as they began to study this matter, adopted the method known as « standard costs », continue to use this method which instead of dividing up the real costs, determines the unit costs of « standard costs » of each ser-

(1) Since 1949, the Chairman has been Mr. FIOC, Assistant Head of the General Studies Department of the S.N.C.F.

vice corresponding to the necessary and inevitable expenses.

The *European Economic Commission* (C.E.E.) of the Economic and Social Council of the United Nations has also studied the problem of transport costing. It has perfected a standard accountancy method for Railway Administrations, the application of which must necessarily be progressive, since most Administrations are bound to their Governments by legal or agreed obligations which will not allow them to modify their accountancy methods as they please.

The *C.E.E.* has adopted a method of calculating railway transport costs based on that perfected by the *U.I.C.* and it has studied the problem of the variation of these costs as a function of the useful load of the wagon and the distance.

The studies have also covered costing transport by road and water.

II. CALCULATION OF THE GENERAL AVERAGE COSTS

The calculation of the general average costs consists of dividing up the expenses of a given year (operating expenses and financial charges) between the various traffic or operating items of the year in question.

It consists of three distinct phases :

(*a*) The determination of the whole of the operating items;

(*b*) The allocation of the expenditures between the various operating items;

(*c*) The determination of the cost of the various traffic items.

1. Determination of the items covered by the year.

Of all methods of transport, the railway is the one which has the most complete statistical documentation.

The statistics form one of the essential elements in ascertaining the average general costs. On the S.N.C.F., they give for each year :

— the *traffic :* passengers carried, passenger-km, tons carried, tons-km per category and sub-category of traffic;

— the *operating :* mileage and gross tons-km hauled for each of the 6 Regions and following 17 categories of trains :

In reality, taking into account the subdivision according to the method of traction (steam, electric, diesel) there are 71 categories of trains to be covered in calculating the general average costs.

These calculations also take into account a great many other statistics, amongst which may be mentioned :

— the number of employees per department;

— the stock of traction and rolling stock hauled per category;

— fuel consumption;

— lengths of line per category;

— number of wagons loaded;

— the kind of traffic.

For the year 1958, the *traffic items* were as follows :

— *Passengers-km* (in millions)	
— suburban	4 350
— main line	27 950
	32 300
— *Tons-km* (in millions)	
— parcels	250
— sundries	1 050
— full wagon loads RA	5 500
— full wagon loads RO	46 100
— *Units-km* (in millions)	85 200

and the *operating items :*

2. Determination of the costs.

The costs are the subject of detailed allocations. The accountancy nomenclature of the Operating Account groups them in 10 chapters under 197 items :

— Chapter 0 : Employers'charges;

— Chapter 1 : General Administration and general costs;

— Chapter 2 : Operating;

	Category No.	Steam locomotives		Electric locomotives	Diesel locomotives and cars	Electric rail motor coaches	Railcars
		Fuel	Coal				
COMMERCIAL TRAINS							
1. *Passenger trains*							
Fast and express trains	1	Vf 1	Vc 1	El 1	D 1	Ea 1	—
Through trains	2	Vf 2	Vc 2	El 2	D 2	Ea 2	—
Stopping trains	3	Vf 3	Vc 3	El 3	D 3	Ea 3	—
Suburban trains	4	—	Vc 4	El 4	—	Ea 4	—
Railcars							
— fast and express	5	—	—	—	—	—	A 5
— through	6	—	—	—	—	—	A 6
— stopping	7	—	—	—	—	—	A 7
— suburban	8	—	—	—	—	—	A 8
2. *Parcels trains*							
Through parcels trains	9	Vf 9	Vc 9	El 9	D 9	Ea 9	A 9
Stopping parcels trains	10	Vf 10	Vc 10	El 10	D 10	Ea 10	A 10
3. *Goods trains*							
Through goods trains	11	Vf 11	Vc 11	El 11	D 11	Ea 11	—
Stopping goods trains	12	Vf 12	Vc 12	El 12	D 12	Ea 12	—
Empty trains							
Passenger trains							
— main line	13	Vf 13	Vc 13	El 13	D 13	Ea 13	A 13
— suburban	14	—	Vc 14	El 14	—	Ea 14	A 14
Goods trains	15	Vf 15	Vc 15	El 15	D 15	Ea 15	—
Service trains							
Passenger type	16	Vf 16	Vc 16	El 16	D 16	Ea 16	A 16
Goods type	17	Vf 17	Vc 17	El 17	D 17	Ea 17	A 17

— Chapter 3 : Traction and Rolling Stock;
— Chapter 4 : Permanent Way and Buildings;
— Chapter 5 : Electric Power;
— Chapter 6 : Marine Department;
— Chapter 7 : Credits and Work for other departments and Third Parties;
— Chapter 8 : Renewal costs.
— Chapter 9 : Financial charges and other miscellaneous charges.

Chapter 0 is in principle balanced at the end of the year by the credits under different headings. In fact, abnormal expenditure on pensions which is the subject of reimbursement from the State comes under this chapter.

The items are divided up into subdivisions, headings and paragraphs, each heading covering five paragraphs :

§ 1 — Staff;
§ 2 — Establishment and divers;
§ 3 — Materials;
§ 4 — Various costs;
§ 5 — Shared costs.

The accounts are therefore an extremely complete documentation. However they

	Passengers trains			Goods trains	Total
	Sub-urban	Main line	Total		
Train runs (in millions of km)					
Commercial trains	20.1	177	197.1	184.3	381.4
Empty and service trains	1.5	7.4	8.9	8	16.9
Total	21.6	184.4	206	192.3	398.3
Gross tons-km hauled (in thousand millions)					
Commercial trains	5	49.7	54.7	137.3	192
Empty and service trains	0.3	1.8	2.1	4.5	6.6
Total	5.3	51.5	56.8	141.8	198.6

record the *real* expenses, whereas the costs must be based on the *normal* expenses. Corrections therefore have to be made to the real costs in order to « normalise » them, especially in the case of costs relating to maintenance and the renewal of the permanent way and installations and sinking fund charges for the rolling stock.

3. Allocation of the expenses as between the various categories of traffic and trains.

The expenses are allocated by article and by group of articles between the traffic items and categories of trains, according to the nature of these costs :

— directly;

— by the use of keys which take statistical data into account;

— by the use of spot checks;

— by applying contractual rules.

For the main expenditure headings, the methods of allocation adopted are as follows:

Chapter 4 (Operating).

The two most important headings under this are those of stations and trains.

The allocation of station expenditure involves 2 stages : a first breakdown between the three great classes of traffic : passengers, goods by accelerated services; goods by ordinary services, followed by a sub-breakdown between categories of trains.

The allocation of the station staff expenses is done by starting from the numbers used for each category of traffic, these being determined by a spot check covering all the unclassified and main stations.

At each of these stations, the permanent regular staff and auxiliary staff are divided up amongst different headings :

— Management;

— Traffic;

— Passengers;

— Luggage;

— Handling;

— Office;

— Shunting.

For each heading, the costs are estimated taking into account the daily wage of an average grade employee in the section in question and the charges are broken down and converted by means of coefficients of ponderation into charges equivalent to the charge chosen as reference.

In the case of the heading « passengers » for example, the basic work is the issue of tickets and the number of tickets issued are modified using the following coefficients of ponderation :

— printed or machine issued tickets	1
— platform tickets	1
— all-stations ticket (internal traffic)	3
— all-stations ticket (international traffic)	5
— weekly season	1
— ordinary season	10
— seat reservation ticket	2

In this way, it is possible to obtain, for each heading, the average unit cost of each work.

Dividing up by category of trains the cost of accompanying the trains as well as the cost of checking and inspecting, are done by means of checks carried out by breaking down the duty sheets of the train staff.

Chapter 3 (Traction and Rolling Stock).

The allocation of the costs of the Traction and Rolling Stock Department is facilitated by detailed accountancy statements by very complete statistics relating to the user of the staff and rolling stock and by studies of the « kilometric cost of traction », which give the breakdown of the costs for each series of motor units or hauled rolling stock.

In the case of the motor units :

— steam locomotives;
— electric locomotives;
— electric rail motorcoaches;
— diesel locomotives and motor units;
— railcars;

the mileage and gross tons-km hauled are got out for each Region, for each category of train and for each series of locomotives.

The kilometric costs per series of locomotives, broken down into labour and materials, are determined under the following headings :

— periodic overhaul;
— non-periodic overhaul;
— driving and service in the sheds;
— power;
— various consumptions (water, lubrication).

In the case of the passenger rolling stock (coaches and railcar trailers), the kilometric cost of periodic and non-periodic maintenance, broken down into labour and materials, are determined for each series of vehicles.

In the case of the goods rolling stock (wagons and vans), it is the average annual cost per category of stock which is established.

The *maintenance costs of traction stock* are divided up for each Region between the different categories of trains, starting from the kilometric cost per type of motor unit and the mileage of each category of trains.

The *maintenance costs of the passenger rolling stock* are allocated for the whole of the S.N.C.F. starting from the kilometric maintenance costs per series of vehicles and the vehicles-km of each series per category of trains.

The *maintenance costs of the goods rolling stock* are also allocated for the whole of the S.N.C.F. starting from the results of checks giving the average composition of the different categories of trains.

The *costs of driving* are first of all divided up between the « line » and « shunting » services. The « line » costs are allocated between the categories of trains from checks carried out by breaking down the rosters of the driving staff which gives the average mileage per set of men or the average number of men per set, and takes into account the average hourly cost per set of enginemen.

The dividing up of the *cost of power* is done :

— in the case of steam locomotives : according to the consumption per train-km given by formulae established per category of train as a function of the gross tonnage hauled per train;

— in the case of electric locomotives : according to the consumption based on the average consumption per gross ton-km per category of trains;

— in the case of diesel locomotives, electric rail motorcoaches and railcars : from the consumption obtained from the average consumption per km for each type of engine and each category of trains.

Chapter 4 (Permanent Way and Buildings).

The costs of the Permanent Way and Buildings Department are divided up per method of traction between the different categories of trains according to either the *gross ton-km* or the train-km as modified by the coefficient of ponderation. These coefficients are got out from the unit costs per category of line.

Lines of category 1 A (lines with heavy fast and express passenger traffic) have costs per km of line 18 times greater than those for lines of category 4 B (coordinated lines with light goods traffic) but their traffic is 110 times greater, which results in the costs per gross ton-km being one sixth lower.

As regards the *financial charges*, the allocations are made :

— in the case of charges for the rolling stock, on the basis of the theoretical annual renewal cost calculated from the value of the renewal of each category of rolling stock and its normal life;

— in the case of charges for building, supplementary work, etc., on the basis of the expenditure on the permanent way, buildings, and various installations;

— in the case of charges for electricity, on the basis of the consumption of electric power;

— in the case of charges for supplies, on the basis of the cost of fuel and the expenditure on materials for maintaining the rolling stock and fixed installations.

The unit values (1958 prices) and the normal life in the case of the main categories of rolling stock are as follows :

	Price (in millions)	Life (in years)
Steam locomotives, type 141 R	110	45
Electric locomotives :		
— express type BB 9200, 1 500 V	129	40
— mixed, type BB 9400, 1 500 V	98	40
— express type BB 16000, 25 000 V	136	40
— mixed, type BB 16500, 25 000 V	102	40
Diesel locomotives :		
— 060 DB, 1 800 HP	124	35
825 HP railcars	90	25
Passenger coaches	47	50
Covered wagon	2.9	50
High-sided wagon	2.35	50

4. Results.

The *average general overall costs* are determined :

— per category of traffic;

— per category of trains.

The processus of the calculation can be shown in diagrammatic form as below (fig. 1 and 2).

The costs per *category of traffic* are obtained after regrouping :

(*a*) the expenses directly allocated to the different categories of traffic;

(*b*) expenses other than the above which have been allocated to the categories of trains, after being divided up between the categories of traffic,

making the quotient of the total expenses by the corresponding services.

In presenting the results, the expenses are regrouped under the following headings :

Operating expenses :

General administrative and general expenses.

Operating Department :

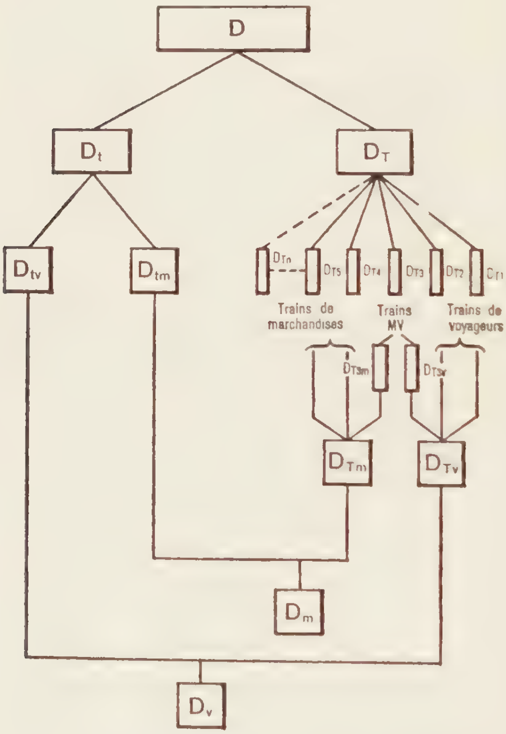
— divisional costs and miscellaneous;
— stations;
— train crews.

Rolling Stock and Traction Department :

— divisional and diverse costs;
— maintenance of traction stock;
— maintenance of rolling stock;
— driving the motor stock;
— fuel, water, lubricants.

Permanent Way and Buildings Department:

— divisional and diverse costs;
— inspection;



D = Total costs to be divided up;

D_t = Costs divided up directly between categories of traffic;

D_T = Costs divided up directly between categories of trains;

D_{tv}, D_{tm} = Subdivision of D_t between passenger and goods traffic;

$D_{T1} + D_{T2} + D_{T3} \dots D_{Tn}$ = Subdivision of D_T between categories of trains 1, 2, 3, 4, 5, ... n;

D_{T3v}, D_{T3m} = Division between passenger and goods traffic of cost for the mixed trains D_{T3};

D_{Tv}, D_{Tm} = Regrouping of the costs of passenger and goods trains;

$D_v = D_{tv} + D_{Tv}$ Passenger traffic costs;

$D_m = D_{tm} + D_{Tm}$ —— Goods traffic costs.

$\dfrac{D_v}{\text{Number of passengers-km}}$ = Average general costs of the passenger-km.

$\dfrac{D_m}{\text{Number of tons-km}}$ = Average general costs of the ton-km.

Fig. 1. — Diagram of calculating the average general costs.

(Divided up per category of traffic)

— maintenance of the track, bridges and subsidiary installations;
— maintenance of buildings and various installations.

Financial charges :

Charges for the traction stock;
Charges for the rolling stock;
Charges for building and supplementary work;
Charges for electrification;
Charges for supplies.

Taxes on the receipts :

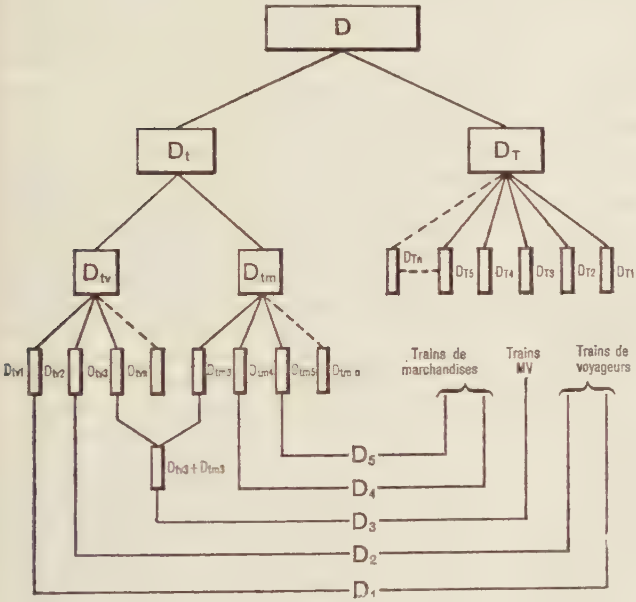
The costs per *category of trains* are obtained in a similar manner by regrouping :

(*a*) The expenses allocated directly between the various categories of trains;

(*b*) Expenses other than the above which have been allocated between the categories of traffic, after having been divided up amongst the categories of trains.

The necessary corrections are made to include in the expenses of the different categories of traffic, expenses in connection with service transport (fuel, ballast, sleepers, various materials).

A further stage in the calculations makes it possible to determine the costs per subcategory of traffic :
— passengers for each class;



D = Total costs to be divided up;

D_t = Costs divided up directly between categories of traffic;

D_T = Costs divided up directly between categories of trains;

D_{tv}, D_{tm} = Subdivision of D_t between passenger and goods traffic;

D_{T1}, D_{T2}, ... D_{Tn} = Subdivision of D_T between train categories 1, 2, 3, 4, 5, ... n;

$D_{tv1} + D_{tv2}$ ..., $D_{tm3} + D_{tm4}$ = Subdivision of D_{tv}, D_{tm} between train categories 1, 2, 3, ... n;

$D_1 = D_{tv1} + D_{T1}$ = Cost of trains of category 1;

$D_2 = D_{tv2} + D_{T2}$ = ——— 2;

$D_3 = D_{tv3} + D_{T3} + D_{tm3}$ —— 3;

$D_4 = D_{tm4} + D_{T4}$ = ——— 4.

$$\frac{D_1}{\text{Numb. of trains-km of cat. 1}} = \left\{ \begin{array}{l} \text{Average} \\ \text{general} \\ \text{cost of the} \\ \text{train-km} \\ \text{of cat. 1.} \end{array} \right. \qquad \frac{D_1}{\text{Numb. of gross tons-km hauled of cat. 1}} = \left\{ \begin{array}{l} \text{Average} \\ \text{general cost} \\ \text{of the gross} \\ \text{ton-km haul-} \\ \text{ed for trains} \\ \text{of cat. 1.} \end{array} \right.$$

Fig. 2. — Diagram of the calculating of average general costs.
(Divided up per category of trains)

— luggage;
— parcels;
— sundries;
— full loads RA (fast regime);
— full loads Ro (slow regime);
— rakes of wagons;
— complete trains;

and to prepare the balance sheet for certain categories of trains :

— T.E.E. trains (Trans-Europ-Express);
— stopping passenger trains;
— complete trains of privately owned wagons.

5. **Closing the balance sheet of the costs.**

A correct calculation of the costs must give a *guarantee of closure*, i.e. for each category of traffic the sum of the expenditure corresponding to each division of the tonnage and mileage must be equal to the total expenditure for the category of traffic under consideration.

The average general costs of a category of traffic corresponds to the barycentric costs of each section of distance or load.

It should be pointed out that this barycentric cost does not coincide with the cost of transport over the average distance by a wagon whose tonnage is equal to the average load.

The general average costs therefore have an abstract significance and differ from the real costs corresponding to the average traffic characteristics.

The coefficient of closure for each category of traffic is determined by making the quotient the barycentre of the estimated costs and the real average general costs. This coefficient takes into account both the barycentric error due to the approximation of the laws of variation of the costs adopted and the material approximations of the different calculations.

6. **Calculation of the average general marginal costs.**

The *average general marginal costs* of a given category of traffic can be defined as the quotient of the variation of the expenses corresponding to the variation in the volume of traffic considered (1).

To carry out such a calculation, it is necessary to know the importance of the variation in the traffic, as well as the reference position from which the costs should be calculated : degree of saturation of the fixed installations, possibility of improving the user of the stock, existence of excess labour. The variation in the expenses due to these data depends moreover on the degree of adaptation of the operating facilities to the level of traffic.

In practice, it is admitted that certain adaptations to the traffic will be carried out in the near future if this has to be stabilised. Simply by pensioning off and writing off, momentary surpluses in labour and rolling stock can be overcome within a few years, and it is logical to consider under these various headings that the position is one of full user, even if this does not correspond to the immediate reality.

The average general marginal costs effectively calculated correspond in general to the costs for the additional traffic which the railway could carry with its existing installations, labour and rolling stock taken as being strictly adapted to traffic requirements.

To estimate these additional costs, an analysis is made item by item of the factors making up the average general costs in order to determine :

— those which are practically invariable;
— those which vary proportionally to the volume of traffic;
— those which vary with the traffic, but according to a different law than mere proportionality.

The main items of expenditure which do not come under the marginal costs are those of the following headings :

— General and regional administrative costs;

(1) See article by M.R. HUTTER in the February 1960 issue of the *Revue Générale des Chemins de Fer* (Dunod, publisher).

— Inspection of the permanent way;
— Maintenance and renewal of buildings and bridges;
— Financial charges in connection with building and electrification.

The items of expenditure to be taken into account in calculating the overall and marginal average general costs are shown in the following table, after regrouping of the expenses under the 25 headings adopted by the C.E.E. (see table on next page).

In the case of items which include labour costs, the total costs take into account the total social and insurance charges (direct charges, indirect charges and fixed charges) and the marginal costs only the direct and indirect social and insurance costs but not the fixed charges.

The average general costs are determined in this way per category and sub-category of traffic, taking into account all the costs which vary with the traffic.

7. Laws of variation of the average general costs as a function of certain parameters.

It is important to know the law of dispersion of the costs as a function of the various parameters, in particular those which affect the tariffs.

The variation of the costs of the different categories of goods traffic is established as a function of the paying distance, d and the weight of the consignment, c. All the other parameters, which come into the calculation of the costs (method of traction, profile of the line, tonnage of the trains), are taken as being constant and equal to the average value for the whole of the traffic in question.

The laws of variation are obtained by taking the sum of the laws of variation of each of the items of expenditure, as a function of the parameters d and c.

These laws can be defined by using the results of checks made on the turn round of the wagons carried out in April 1958, which in particular made it possible to find out :

— the laws of variation of the mileage of the pick-up trains as a function of the total mileage;
— the laws of variation of the number of marshalling yards on the run as a function of the transport distance.

In the case of wagons sent by ordinary slow goods trains (RO), the average number n of marshalling yards on the run, as a function of the transport distance d, is :

— in the case of loaded wagons :

$$n = \frac{\sqrt[3]{d}}{2.25} ;$$

— in the case of empty wagons :

$$n = \frac{\sqrt[3]{d}}{3.2} .$$

These variations are shown on the graph given below (fig. 3).

In the case of traffic in full loads sent by ordinary slow goods (RO) from station to station, the costs can be broken down into :

— expenses in connection with the terminal operations on arrival and departure (clerical work, checking, stabling of rolling stock);
— expenses in connection with marshalling (marshalling and stabling the rolling stock);
— running expenses.

Taking into account the average percentages for return and empty runs of the wagons, the turn round of the wagons r, as a function of the paying distance d, is given by the formula :

$$r = 4.77 + 0.43 \sqrt[3]{d} + 0.0024\, d$$

and the average general cost per useful ton (in indices) is :

$$P = 8 + 0.092\, d + \frac{482 + 1.53\, d + 42 \sqrt[3]{d}}{c} ,$$

$$\text{for } d \geqslant 80 \text{ km}$$

$$\text{with } P = \frac{354}{c} \text{ for } d = 0,$$

which leads to the variations in the costs shown in the following graph (fig. 4).

Items of expenditure	Costs		Remarks
	overall	marginal	
1. General administration and general costs	t_1	—	
2. Other general costs	t_2	—	
3. Social and insurance costs	—	—	The labour costs under each heading are increased by these amounts.
4. Taxes :			
— Taxes borne by the railways	t_4	—	
— Taxes collected on behalf of the State	—	—	The receipts are reduced by these amounts.
5. Commercial and diverse charges	t_5	—	
6. Compensation for accidents	t_6	t_6	
7. Terminal operations at stations	t_7	t_7	
8. Handling	t_8	t_8	
9. Shunting	t_9	t_9	
10. Other station expenses	t_{10}	—	
11. Train staff	t_{11}	t_{11}	
12. Haulage	t_{12}	t_{12}	
13. Service in sheds and preparation of traction units	t_{13}	t'_{13}	t'_{13} corresponds to the cost of preparation of the traction units.
14. Driving	t_{14}	t_{14}	
15. Fuel or power	t_{15}	t_{15}	
16. Lubrication and diverse	t_{16}	t_{16}	
17. Maintenance and repair of traction stock	t_{17}	t_{17}	
18. Maintenance and repair of rolling stock	t_{18}	t_{18}	
19. Sinking fund and renewal of traction and rolling stock	t_{19}	t'_{19}	t_{19}: renewal charges; t'_{19} : interest and sinking fund charges.
20. Inspection of permanent way, maintenance and renewal of the track and structures	t_{20}	t'_{20}	t'_{20} corresponds to costs due to wear of the track.
21. Maintenance and renewal of the station installations, depots and shops, buildings and service accommodation	t_{21}	—	
22. Maintenance, renewal and inspection of fixed installations for electric traction	t_{22}	—	
23. Signals and telecommunications	t_{23}	—	
24. Financial charges	t_{24}	—	
25. Funds held debited to the operating account, other sinking fund and renewal charges	t_{25}	—	

The costs therefore show a decrease with the distance which is due mainly to the variation in the number of marshalling yards run through.

The fanning out of the costs of goods transport is therefore very marked : the cost per ton-km for carrying a 20 kg parcel 25 km is about 200 times greater than that of carrying heavy goods in complete train loads of 1 800 tons-1 000 km.

I being the index of variation of the prices as between the years A and B,

$f(t)$ the law of variation of the cost a as a function of the traffic, and

k the coefficient of balancing closure.

The indices used are :

S = « staff » index (annual cost of the average employee);

M = « materials » index (index of the cost of materials consumed by the S.N.C.F.);

C = « fuel » index (cost per ton of coal on the tender);

E = « electricity » index (cost of high tension kWh at the substation entry);

G = « diesel fuel » index (cost per kg of diesel fuel);

R = « rolling stock » index (cost of traction and rolling stock);

F = « financial charges » index (cost of the financial charges of the S.N.C.F.).

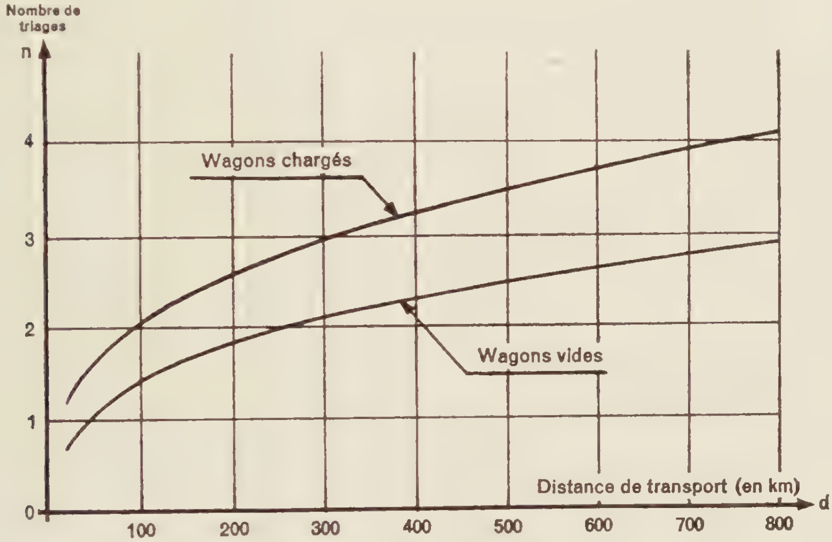


Fig. 3.

N. B. — Nombre de triages = number of times marshalled. — Wagons chargés = loaded wagons. — Wagons vides = empty wagons. — Distance de transport (en km) = transport distance (in km).

8. Indexing the costs.

In periods of relative stability of prices and traffic, it is not necessary to make a new calculation of the average general costs each year.

The costs for the year B can be obtained from those for the year A by a method of indexing.

To the cost a for each of the items of expenditure for the year A corresponds a cost b for the year B, so that :

$$b = a \cdot \mathrm{I} \cdot f(t) \cdot k$$

This method makes it possible to determine the costs relating to a period the traffic and price characteristics of which are known. It can also be used to calculate the provisional costs corresponding to the budgets got out from statistical and accountancy estimates.

The method is used for calculating the average general costs and particular costs, both overall and marginal.

III. CALCULATION OF PARTICULAR COSTS

When the average general costs are made by the analytical method, calculations of particular costs have a synthetic character.

They may cover :

— either traffic to or from given stations;

— or all the traffic in one kind of goods or group of goods, coming under the same tariff for example.

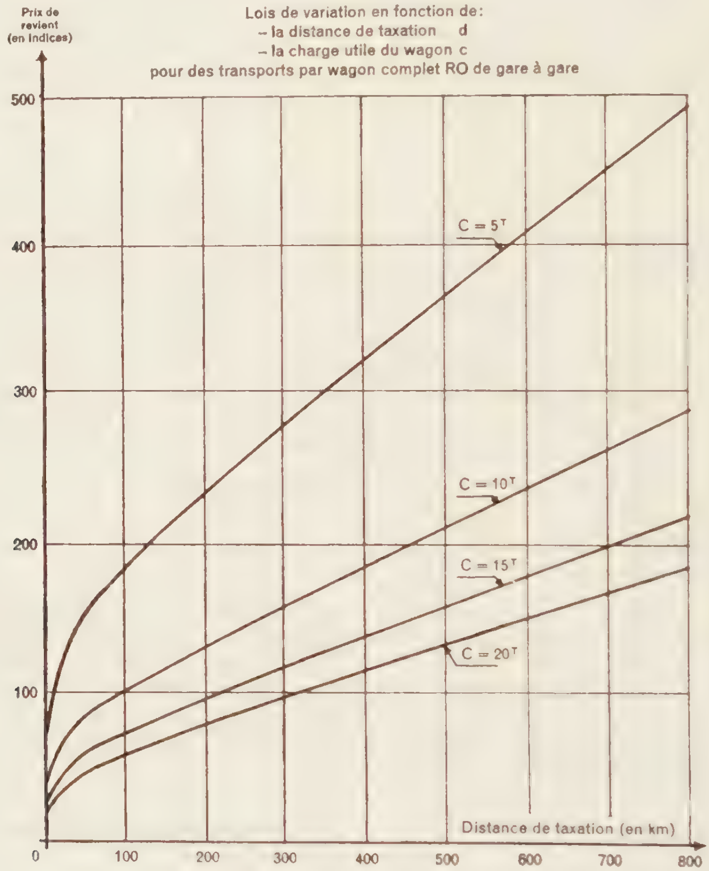


Fig. 4. — Average general overall costs per useful ton.

N. B. — Prix de revient (en indices) = cost price (in indices) — Lois de variation en fonction de : = laws of variation as a function of : - - la distance de taxation *d* - fare stage *d* — - la charge utile du wagon *c* — - payload of wagon *c* — pour des transports par wagon complet RO de gare à gare = for full wagon loads, ordinary slow goods (RO), station to station. Distance de taxation (en km) = rated distance (in km).

Calculating particular costs includes :

1. A detailed analysis of the characteristics of the traffic being studied :

— characteristics of the route, length, profile, categories of line;
— traffic carried : nature, tonnage, regularity;
— trains used : class, tonnage, stops;
— stock to be used : type of wagons, payload;
— movement of empty wagons;
— method of traction, types of locomotives, duration of run, consumption of power, light running.

Such an analysis necessitates a very thorough knowledge of all the operating conditions.

2. The determination of the operating charges corresponding to the traffic under study.

Units of measurement have to be decided upon for each heading. They may be :

— the train-km;
— the locomotive-km;
— the wagon-km;
— the wagon-day;
— the man-hour.

3. The determination of the unit prices to be taken into consideration for each of the charges.

These unit prices are :

— either determined directly (cost of driving, power, maintenance of the motor stock, obtained from studies of the kilometric costs of traction for each series of locomotives);
— or deduced from the study of the average general costs :
  — cost of elementary operations (clerical, shunting) carried out at each station;
  — general administrative costs.

Interest and sinking fund charges are the subject of a direct calculation taking into account :

— the replacement value of the stock;
— its life;
— its conditions of user.

The particular costs of the transport under study is obtained by adding together the products of the unit costs by the corresponding numbers of charges.

Calculations of particular costs, like those of the average general costs, can relate either to the total costs or the marginal costs.

The general method given above corresponds to a calculation of the total costs; it assures the balancing closure of the whole of the operating expenses.

In calculating marginal particular costs, it is only necessary to leave out those constituents which are fixed so that they need not be taken into account : general charges, maintenance of the fixed installations, financial charges in connection with the fixed installations.

The calculation of the particular costs may include a great number of variants, so that it is often a very technical and skilled matter which always requires a great deal of initiative.

IV. APPLICATIONS OF CALCULATIONS OF COSTS

Calculations of the *average general costs* make it possible :

1. to prepare the general operating balance sheet of the S.N.C.F. per category of traffic;
2. to supply the Commercial Department with the necessary information for their general tariff studies.

The pre 1947 goods tariffs of the French railways were based on a system of quasi monopoly. The chief factor taken into account was the value of the use made of transport.

The development of road transport meant that the railway was faced with general competition and was obliged to make changes in its goods tariffs, which would take its costs into account. This principle was put forward in the decree of the 14th November 1949 on the co-ordination and harmonisation of railway and road transport.

It is admitted in principle that for each transport, the charge made must be higher than the marginal cost of the transport, but must remain lower on the one hand than the price asked by competitors and on the other its value as a going concern.

The successive stages of the overhauling of the goods tariffs of the S.N.C.F. in order to bring them as closely into line with the costs as possible were as follows :

— in 1947, general reform of the tariffs, taking into account in particular the preponderant influence on the costs of the wagon load;
— in 1951, differential scales according to the services by means of the station index system;
— in 1953, increasing the rates for sundries traffic and wagons with small part loads, which did not cover the costs satisfactorily;
— in 1957, a further increase in the rates for wagons with small part loads;
— in 1958, overhaul of the station index system.

3. establishing of a great many elementary costs (cost of terminal operations in the stations, traction costs per category of trains, rolling stock costs par category of vehicle) which it was essential to know in order to be able to calculate particular costs;

4. controlling the efficiency of operating, by comparing the costs of different establishments, services and even Regions. For such comparisons, it must naturally not be forgotten that the costs also depend upon certain factors (kind of installations, nature of the traffic) lying outside the control of the staff.

The field of application of *particular costs* is extremely vast. It includes in particular:

1. The determination of the most economic routes.

The marginal traffic costs in each direction have been calculated for each section of the line, taking into account :

— the profile of the line;
— the method of traction;
— the gross tonnage hauled per train;

taking into consideration only those costs which vary with the route taken, under the following headings :

— train staff;
— engine crews;
— preparation of the traction units;
— power;
— lubricating, other materials, and various;
— maintenance and repair of traction stock;
— sinking fund and renewals of traction stock;
— maintenance of rolling stock;
— sinking fund and renewal of rolling stock;
— maintenance of the permanent way (costs varying with the traffic).

The costs per gross ton-km hauled in the case of a full wagon load (11 t tare and 19 t payload) have made it possible to determine the « fictitious » distance of each section of the line, which might be defined as the product of the real distance by the ratio between the marginal cost per gross ton-km hauled on the section of line in question and the average marginal cost per gross ton-km.

Marshalling costs under the following headings :

— shunting locomotives;
— operating staff;
— periodic maintenance of the wagons;
— interest and sinking fund charges on wagons;
— maintenance of the permanent way and installations (costs varying with the traffic);

have been estimated for each wagon shunted, then transformed per gross ton in order to obtain a fictitious distance corresponding with the wagon being in the marshalling yard.

These data have been filled in on maps which make it possible to determine the most economic route for each transport.

It has been clearly defined that in cases where the use of such documents would lead :

— either to an important transfer of traffic

leading to the saturation of one route and additional capital costs;

— or to different routes according to the direction of the traffic, more thorough studies are to be carried out.

If the « station indices » were the first step in adapting the tariffs to the costs according to the routes, a further stage might be to base the charges on the *weighted distances*.

Instead of the short distances between the fare stages the « weighted distances » would be substituted, which for each section of the line are equal to the product of the actual distance by a coefficient which is a function of the cost of transporting goods over this section.

Studies have also been carried out to determine the most economic routes for international traffic (for example oranges from Spain to Germany).

2. The determination of the charges for services carried out on behalf of a third party (postal traffic, exchanges of stock with foreign Administrations).

3. The preparation of economic balance sheets for changing over to diesel or electric traction from steam traction for services on a line or group of lines or for shunting. This question was the subject of the U.I.C. Leaflet No. 371 and S.N.C.F. General Instructions Leaflet No. D4 giving the Regions the necessary directives to enable them to prepare balance sheets from the same basic principles.

4. The preparation of balance sheets for the substitution of road services for railway services on lines with very little traffic. This question is dealt with in U.I.C. Leaflet No. 372 and the General Instructions Leaflet D3 gives the Regions all the details necessary for preparing such balance sheets, which make it possible to compare the savings, if necessary after modernisation, that would be obtained by suppressing the railway services with the costs of the road services replacing them, taking into account the loss of receipts from end to end which might be caused by loss of traffic. Very numerous balance sheets, covering some 9 000 km of lines or so have already been prepared by the different Regions applying these principles.

5. The establishment of the necessary information for co-ordination studies : competition with waterways (canalisation of the Moselle, North Canal); National Transport Accounts Commission (equipment of the Paris-Lyons-Marseilles artery).

V. CONCLUSION

On the S.N.C.F. studies of costs have been allocated to a group of specialists of the « General Studies » Department, working in close collaboration with the Management and Regions. It appeared preferable for the Department responsible for such studies to be independent of the Department making use of the results, so as to avoid any of the calculations taking on a subjective character.

In addition, the studies have not been decentralised in order to avoid the presentation of divergent calculations, which would not meet the essential requirements of all calculations of costs : strict objectivity and a guarantee of the balance sheet of the real expenses being closed.

Since its creation in 1938, the S.N.C.F. has devoted much care to the development of its method of calculating costs, and continues to make improvements thereto in conjunction with the other Railway Administrations belonging to the U.I.C.

With the methods that have been perfected, it is now possible to answer any question that may be raised in the very vast field of the costs of railway transport.

[656 .254 (44)]

Calling out the breakdown staff with the minimum delay by means of very low frequency currents,

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(*Revue Générale des Chemins de Fer*, October 1960.)

The electrifications and modernisation of the French Railways have resulted in high concentrations of traffic on certain routes equipped to give a large output economically. Any interruption of any duration on such lines may result in serious train delays in close succession, which may become very troublesome. It was to reduce to the minimum the consequences of this vulnerable position that the Central and Regional Departments of the S.N.C.F. have studied and perfected over recent years improvements which cover both the material means to be put in hand as well as the actual organisation of the so-called breakdown services.

It is within the framework of this research that the South-Eastern Region is making a trial at the present time of a method enabling to call out simultaneously all the members of the breakdown gangs attached to the railway centre of Villeneuve-Saint-Georges.

The Departments taking part in these trials are :

— the Traction Department, which has an 85 t crane, a 50 t crane and a breakdown van;

— the Permanent Way Department, which has « catenary » gangs and « permanent way » gangs to deal immediately with breakdowns.

The Villeneuve-Saint-Georges centre was chosen because it fulfils all the conditions justifying the use of simultaneously calling out the staff concerned;

— it forms, 15 km (9 miles) from Paris, the first railway junction encountered on the great electrified Paris-Lyons artery;

— important breakdown facilities are available;

— the dwellings of the staff are widely scattered.

Principle.

The principle of the installations consists in profiting by the electric light network of the French Electricity Board (E.D.F.) by making use of the neutral wire of the three phase alternating supply, and causing a periodic variation at an infra-acoustic frequency of the potential of this wire in relation to the earth.

This periodic variation in the voltage lasts for a few seconds when it is desired to alert the staff, by means of a 48 V battery, the polarity of which is reversed at the desired frequency. The frequency of the reversal of the direction of the current characterizes the call; a given frequency is allocated to each breakdown gang.

The receiving device, fitted in the home of each member of the breakdown gang, sounds an alarm bell.

In order to assure the correct propagation of the warning current over the whole low tension network, it is essential for the

neutral wires of the different transformer posts to be interconnected.

This interconnection is carefully arranged at as many points as possible (at least two per transformer post) in order to make sure the interconnections as low as possible in order to facilitate the passage of the low tension currents.

Figure 1 gives the general plan of Villeneuve-Saint-Georges, showing the various

Fig. 1. — Calling out zone.

⊙ Transmitting post.
• Receiving post.
– — — Limit of interconnected zones.
N. B. — Echelle = scale.

that the signals will be given in cases when repairs to the network make it necessary to interrupt momentarily one of the connections. Naturally, steps have been taken to make the resistance of the contacts on interconnected zones and the sites of the receiving equipments.

The telecontrol voltage of the call receiving equipment is a function of the characteristics of the network, of the num-

ber of « earths » and of their qualities. In principle, for a normal voltage of 48 V the number of E.D.F. distribution zones should not exceed three. This latter figure, however, must be determined in each case, as it is a function of the neutral-earth

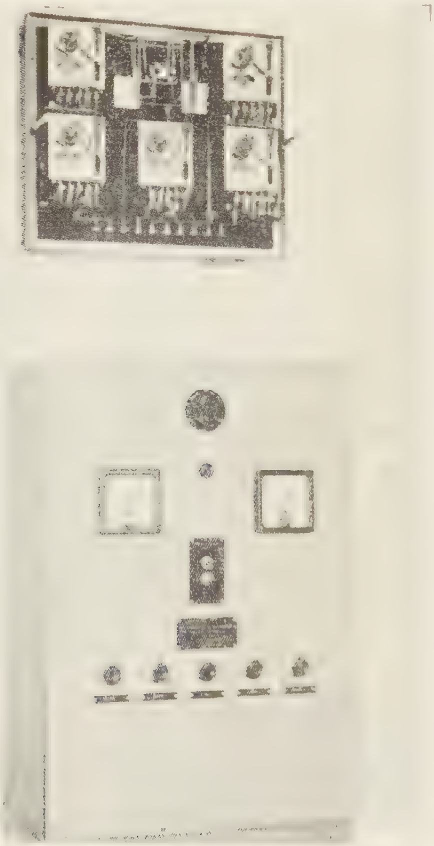


Fig. 2. — Transmitting equipment: chronometric relays.

resistance on which the working of the system is based. This resistance, however, which had a far from negligible value in the case of the old overhead networks which were earthed by means of grid-plates or rod stakes, is very low in the case of modern networks using cables in which the neutral is connected to the lead of the cable. In this case, it is necessary to take steps to define the possibilities of calling up and, if necessary, regulate the sensitivity of the receiving relays. At Villeneuve-Saint-Georges, the relays had to be sensitized in certain zones.

Description of the apparatus.

1. *Transmitter apparatus.*

The transmission problem is to make the potential of the neutral wire oscillate in relation to the earth according to a predetermined frequency, such a frequency having as many values as it is desired to make different calls (five in the case of Villeneuve-Saint-Georges, the maximum being 10, ranging between 0.4 and 2 c/s).

Transmission takes place by means of a battery of accumulators fitted between the neutral of the town lighting network and an earth, the connection varying alternatively in each direction by means of a reversing switch controlled by chronometrical equipment at the desired frequency.

The transmitting post (fig. 2) therefore consists of:

— a battery of accumulators with charging equipment;

— chronometrical components equal in number to the number of different calls to be sent out;

— a transmitting reversing switch;

— accessory components (intermediate relays, signal lamps).

The chronometrical relay consists of a pendulum and an anchor-escapement, the fork of which carries a pin which in oscillating comes alternately into contact with two elastic blades on either side of its dead point. These two blades act as contacts and control, by means of a polarised relay, the reversing switch.

The chronometrical relay is driven by a weight which is wound up at the moment of emission by a plunger electro-magnet.

The reversing switch is formed of a group of two bipolar switches mounted as a re-

versing switch. The calibre selected depends on the intensity of the emission.

The working of the transmitting post is simple; it is only necessary to press the button corresponding to the call it is desired to put out.

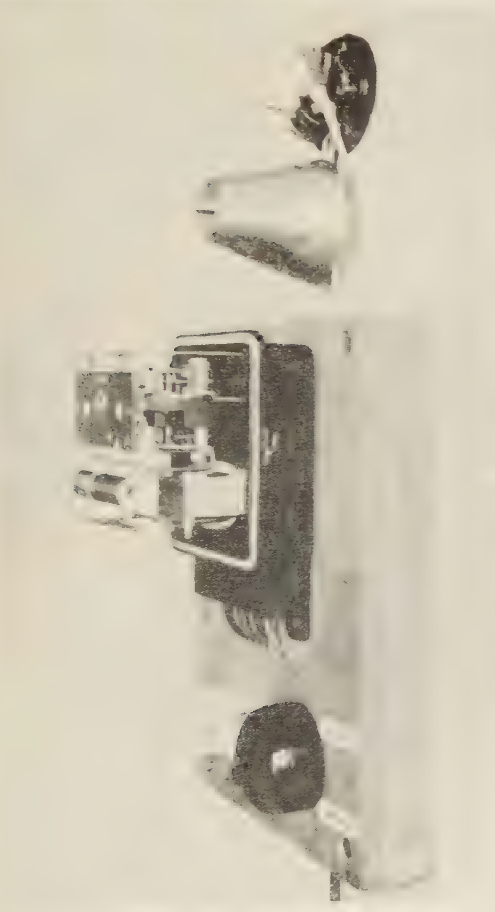


Fig. 3. — Receiving apparatus : selective relays.

The driving weight of the corresponding chronometrical relay is then automatically wound up and the relay thereby started controls by means of a polarised relay the coils of the switch which cause at the desired frequency, the inversions of the current in the neutral earth circuit. When the driving weight of the chronometric relay reaches the end of its travel (after about 50 sec) the transmission ends.

The transmitting apparatus is installed in the Villeneuve-Saint-Georges station, and is operated by the station inspector.

2. *Receiving apparatus.*

The receiving relays (fig. 3), one in each house, are looped in between the neutral wire of the lighting installation and an earth of any quality. The resistance of the relay is very high.

The receiving relay simply consists of a selective relay which directly controls a bell.

It consists of mobile equipment mounted on pivots, with very little damping. The equipment includes a spindle, the pivot of which is carried on jewels, supporting a coiled frame placed in the field of a permanent magnet, and two threaded arms supporting runners, the distance between which in relation to the spindle can be adjusted in such a way as to give the moment of inertia of the whole assembly the desired value corresponding to a definite frequency of oscillation. Two hair springs supply the torsion couple. One of the threaded arms carries a contact piece which for a certain amplitude of movement of the mobile part (about 45°) rubs against a contact blade closing the bell contact.

The mobile frame is fitted between the neutral and the earth through an adjustable resistance (or a smoothing coil), intended to protect it in case of accidental overvoltage and to adapt its sensitivity to local conditions.

The receiving apparatus begins to function with a receiving voltage of 0.3 V, but the voltage may be ten times as high as this without causing trouble.

Stray D.C. currents due in particular to earth currents from the traction current have no appreciable influence on the relays even if their value reaches 150 times the minimum value at which the relay functions.

In addition, the effects of industrial frequency 25 or 50 cycle currents are zero owing to the high value of the moment of inertia of the relays. The selection of the different calls is assured with a sufficient safety coefficient for receiving voltages varying in the ratio of 1 to 10 by spacing the different frequencies amongst them by about 15 % of their respective values.

The functioning of a selective relay is simple : when transmission begins, the mobile frame is subjected to the voltage which the transmitting post sets up in the neutral-earth circuit. If the oscillation frequency of the selective relay in question is equal to the frequency of the transmission current, the mobile equipment comes into resonance and soon reaches a very high amplitude. When this amplitude reaches some 45°, the mobile contact rubs against the fixed contact blade and the bell rings at each elongation.

From the point of view of installation costs, compared with the cost of installing urban telephones, this system is definitely cheaper when the number of employees to be called out is more than 10 in the case of a transmitter with a five call code.

Conclusions.

The solution of the problem of calling out employees by using equipment for low frequency currents must not be considered as a universal solution. It is true that whenever possible the classic telephone should be used. This is the case in particular at centres where the men live close together, when the installation of a telephone in one or two blocks makes it possible to solve the problem, as the caretaker or appointed employee can then call out all those concerned.

However, calling out the men directly by telephone or by low frequency currents instead of the classic knockers-up, reduces the delay in getting out the breakdown gangs by about 50 %. This single result must encourage the extension of this method of calling out to all large centres, since it makes it possible to reduce delays on the main lines to the same extent.

[656 .25 (52)]

JNR's signal and safety systems and their features,

by Yanao HIYOSHI,

Signal Section Chief, Electricity Department.
Japanese National Railways.

(*Japan Commercial Gazette*, July 30, 1960.)

Japanese population of extremely high density is approximately 90 million. This enormous number of people are living on the four islands aligned in a form of a crescent, keeping up their vigorous industrial activities. Consequently, the transportation setup of Japan has certain characteristics that are different from those of ordinary continental countries.

Such characteristics of the Japanese National Railways together with the roles of its signal appliances are described herewith.

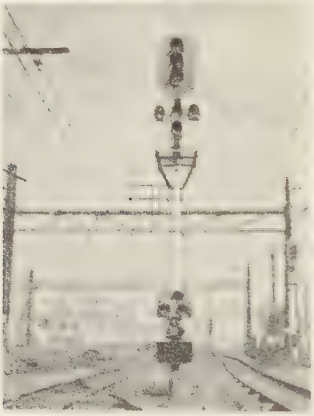
Bird's-eye view of busy traffic of electric-car trains at the Tokyo Central Station.

I. The trunk line transportation.

Having so many urban communities lined up along the trunk lines, traversing the island country, the transportation by passenger and freight trains is immensely busy. For example, the Tokaido-Line, which is the trunk line running along the Pacific Coast of the country over the distance of 587 km between Tokyo and Kobe, is in contact on its path with six major cities of more than one million population, including Tokyo, which holds eight million people within its city limit. These cities are playing important roles as industrial and commercial centers in Japan. It is apparent that in this situation, the trunk line which links these important cities requires a great transportation strength.

On the other hand, the railroad facilities of the country as a whole are not sufficient

to satisfy the all transportation requirement, and are forced to run trains as often as the near-maximum track capacity allows, on both single and double tracks. Thus the transportation requirement has been fulfilled by elevating the rate of full use of tracks as much as possible, avoiding expansion of railroad tracks that necessitates colossal amounts of investment capital.



Starting signal.

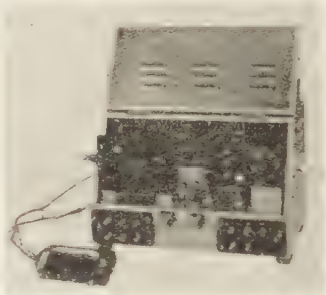
On the Japanese National Railways, the single track section constitutes 86.3 % of total route kilometrage of 20 357. On the majority of the trunk lines of the single tracks, frequency of train runs reaches 80-90 daily, surpassing the 50, which is the usual maximum frequency of train runs in European and American countries, intensifying highly effective operations.

The double tracks in some sections also carry on busy train traffic which reaches 280 train-runs daily.

These frequencies on single and double tracks seem to have almost reached the limits.

Such busy train traffic of high efficiency now in practice in this country urges installation of superbly dependable signal and safety appliances, allied with excellent driving and controlling techniques which can be obtained only through years' experience and tradition.

Average length of a block section of the Japanese National Railways is in the neighbourhood of one kilometre in automatic block sections of double tracks, and 4.5 km in tablet block sections of single tracks.



Train identification device oscillator.

The shorter length of block section than of other countries is one of the biggest reasons which enable the highly frequent train runs in Japan.

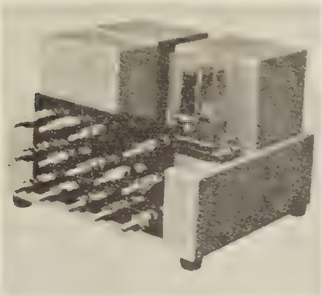
The automatic block system has been in use for a long time and, by now, 99 %

Cable-type interlocking.

of the whole double track lines, 2 781 km, are equipped with the automatic block system and the single track lines are switching the block system to automatic one to meet the growing demand for transport.

Majority of the automatic block system

is equipped with the block signal which is mostly installed so as to enable preceding train and following train run at intervals of 3-6 min. In this case as a general rule, three-aspect signaling system is used. And, in case of necessity, five-aspect signaling system is used adding the



Car detector (electric treadle).

reduced speed signal and restricted speed signal.

Working efficiency of stations, many of which have very complicated layouts of tracks, affects whole transportation a great deal. Especially operative efficiency of terminal stations, composing stations of freight

Electric switch machine.

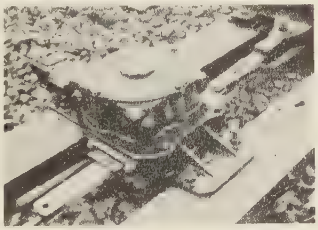
trains and locomotive replacing stations affects directly the time schedules of trains.

Therefore, a relay interlocking device of high efficiency is installed in complicated and important stations.

Quite a number of switches can be switched by one operator or two using a push button to open the route as scheduled, satisfy all locking conditions concerned, and display signals accordingly. Thus operational control under absolutely safe arrangement is performed.

Simultaneous entrance of trains bear dangers of contact accidents and the like in their passages in case a train happens to overrun, and is a sort of headache to officials. The Japanese National Railways solved this problem by laying safety sidings and adopting restricted speed signal, to have many stations let trains enter at same time. That can be included in the reasons for the specially frequent train runs on single-track sections.

In the train of trunk lines, a so-called cab warning device is installed to display the warning according to the signal indica-



Switch-and-lock movement.

tion on the ground, being effective to prevent collisions from behind, caused by ignoring or misunderstanding of signals.

The signal and safety appliances, such as the car retarder of a large-scale marshalling yard and automatic freight classification device, as well as the adoption of the C.T.C. (Centralized Traffic Control device), are playing vital roles in promotion of transportation efficiency and ensuring safety rate.

II. About transportation of commuters.

Commuter transportation around Tokyo and Osaka areas is one of the J.N.R.'s important missions.

A day of Tokyo begins with the gigantic transportation of commuters' trains coming

in various radial directions to business center of Tokyo every morning except Sunday and holidays.

Despite the J.N.R.'s desperate efforts, the number of people who are brought into Tokyo's business center from its suburbs has been constantly increasing to create uncontrollable commotion both in trains and stations. Almost every train of any section of the railways carries overcapacity crowds, approximately 2.5-3 times more than fixed number of passengers.

The congestion has never been eased betraying the efforts of the J.N.R. officials who have been striving to figure out countermeasures such as composition of longer trains with more cars, elevation of performance of rolling stock and more frequent service of trains.

Recently, in suburbs of Tokyo, 10-car (200-m long) electric trains are running at intervals of 2 min, similar to the New York Subway's 10-car formation (183-m long) and the 8-car composition of the Moscow Subway (151-m in length). And the highest frequency per day of electric train traffic on double track lines is about 670 times up and down.

Trains of several different lines arrive and leave Tokyo Central Station every day, totaling the whole train run frequently to 2 100 daily.

Such surprisingly busy train traffic can be managed only with the back up of perfectly functioned, entirely dependable signal and safety installations.

In the first place, all signals on route of those electric car trains are automatic and the cab warning device is applied in the sections where electric motor car trains are operated.

In case a passenger train or freight train runs on the same track of electric car trains, the train identification device is adopted (on the Chu-o Line).

As there is a difference in brake distance according to kinds of trains, this identification device is so designed as to give instruction to the signal on the ground for speed limitation corresponding to the kinds of trains.

Also an automatic interlocking device is used in each terminal and shuttle operation stations. This versatile device enables entirely automatic operation of signals as well as setting route of trains, without any manual help, for regular traffic of trains; and in case of delayed schedule of electric car trains or changing route of an arriving train, can be used as same as ordinary relay interlocking device.

III. About sections with less train runs.

Included in the whole route kilometrage of the Japanese National Railways, there are not a few railroad sections of comparatively less traffic. It is considered that arrangement should be made to make investment in the installations of these sections as less as possible and, at the same time, try to keep their personnel expense minimum, in order to set up a system of most economical transportation.

The block section unifying apparatus is used on occasions such as described below :

In order to abolish night duties of employees of intermediate stations, when all the trains pass through during night hours, the blocking operation at these stations is liable to be suspended during that time only, having several block sections unified to become one single block section.

In such a case, a block section unifying lever is installed in each station to be unified. By using this lever, related signals and switches are locked in proper conditions and then the token block instrument of each station can be disconnected from blocking circuit, and be connected directly with its immediate neighbour station, both up and down lines, to accomplish the unification of block sections.

Usually, the spring switches are used in stations whose track layouts are comparatively simple. This kind of switches do not require stationing of points man or switch man. The power of spring enables the switch stay open towards a fixed direction and, when a train passes through the switch in the reverse direction, the train runs

through by opening the tongue rail with a push of its own power.

In late, the tokenless block system came into practice. This system does not require the use of the tablet and allow trains run, only depending on the indications of signals. The signaling appliances are controlled by short track circuits which are installed at both entrance and exit of the block section.

IV. Alternating current electrification.

Aiming at modernization of power, the 20 kV alternating current electrification of 50 c/s or 60 c/s commercial frequency has been steadily developing. Following the implementation of the alternating current electrification, various technical problems concerning the signal and safety equipment arose.

Scene of Tokyo Central Station during rush hours.

This system has advantages as follows: The blocking and signal were combined in operation; to prevent slowing down of speed of passing trains that used to be caused by the handing and receiving of the tablet while passing a station, and save trouble of station employees.

A new and different experiment, a system called the simplified C.T.C. was introduced. Its blocking method adopted the tokenless blocking system. And for the safety appliance in the station compound, the simple relay interlocking device (which uses the spring switch instead of power switch machine for the switch). This is a C.T.C. which cuts the installation expense to a limit and is expected to be popular in the future.

The most controversial problem is that the commercial frequency track circuit, which has been used for control of automatic signal, will not be used. That is a natural consequence as long as the rail is used as the return route of the electric currency of power-driven cars. To solve the problem, about 1-5 kc audio frequency track circuit (A.F. track circuit) was developed. This circuit employs the techniques of the electronics to some extent as differentiated from conventional one.

Also a track circuit which uses special frequencies, like the 2-phase, 4-wire-type, 83.3 c/s track circuit, has been in use.

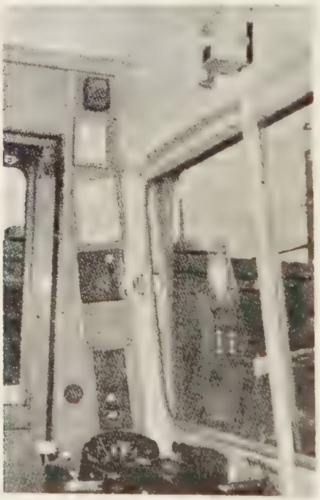
An A.C.-D.C. change-over device is installed in the compound of the junction station of A.C. electrified section and D.C.

electrified section. (A.C. : alternating current. D.C. : direct current.) Then an interlocking device will be required to meet the following conditions in addition

B-type cab warning device receiving coil.

to the roles the interlocking device possesses.

1. Attach an electric source change-over apparatus to the trolley wire to be used



B-type cab warning device.

mutually by direct and alternating current locomotives, to set up an installation which enables the change-over of the electric source of a certain section of trolley wire to 1.5 kV direct current or 20 kV alternating current.

2. When a locomotive is posted in the section in question, it is not permitted to impress a different voltage. So, for the purpose of identifying a locomotive whether it is a direct current locomotive or an alternating current one, a detector is installed.

3. In case an electric source of different kind from that of a locomotive is supplied by the interlockings between the electric source of trolley wire and the signal equipment.

Such a relay interlocking apparatus, described above, is installed in a junction station.

B-type cab warning device receiver.

V. New signaling techniques.

Several of the new signaling techniques which have the cab warning device adopted by the J.N.R. will be introduced herewith.

1. As a train is approaching a stop signal, the cab warning device works automatically to give a warning on the train. Although the idea of this device has been in existence rather a long time, the J.N.R. put it into practice by adopting the following three types which had been developed by the good command of electronic techniques.

a) A-type cab warning device.

This is installed in trains of trunk lines. The warning indication is shown by re-

ceiving on the train the 1 300 c/s carrier, which was superposed on the track circuit of the commercial frequency. This system indicates three kinds of warning indication by detecting the carrier modulated by two kinds of low frequency.

b) B-type cab warning device.

This system is mainly for sections exclusively used for electric-car trains. As an electric-car train is nearing a certain point to the stop signal, the power supply of commercial frequency of the track circuit is stopped by detecting the approach of the train done by a special relay on the ground. Since the train runs usually receiving electric current of track circuit, it gives a warning when the sending current is cut off.

c) C-type cab warning device.

This one is mostly used for semi-trunk lines, and can be installed even where no track circuit exists. An oscillator installed on the train oscillates constantly at 100 kc. On the other hand, a resonance circuit, which was tuned to 130 kc, is placed on the track between rails.

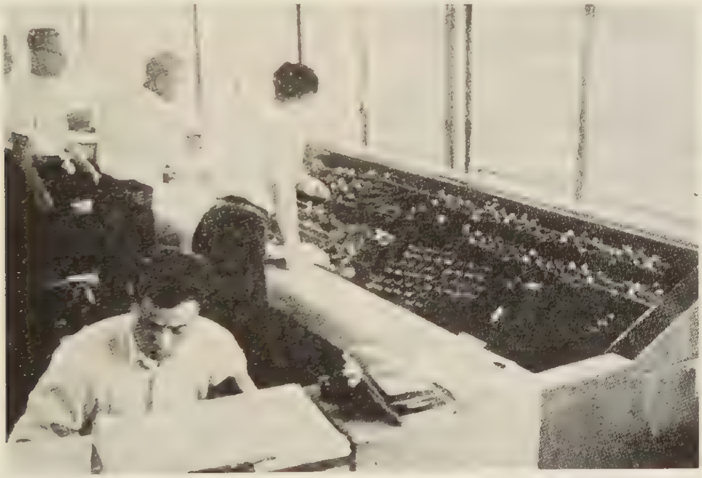
The C-type cab warning device utilizes the change of oscillation frequency caused by the coupling of the oscillation circuit on the train and the resonance circuit on the ground as the train runs on the resonance circuit.

2. Car detector (electric treadle).

For controlling the highway crossing signal, the use of the continuous track circuit is the best. But this setup has a disadvantage of large expense when it is applied in electrified section of a line. However, if another track circuit can be formed over the track circuit already installed, the control of the highway warning signal can be done without changing the existing track circuit.

The car detector was devised out of above mentioned idea. Using the rail as a part of oscillation circuit, oscillates 10 kc frequency, the relay contained in the detector falls as the oscillation stops upon arrival of the train at the spot.

Length of the track circuit is in the neighbourhood of 10 to 20 m and one of the advantages with this detector is that it does



Signaling center of Tokyo Central Station.

not need the rail insulation. All sets use the transistor.

In addition, an apparatus which distincts speed of each train is in use to prevent irregular warning time of the highway crossing signal that may be caused by different speed of running trains.

3. Cable-type interlocking.

Despite the fact that it is possible to save considerable amount of personnel expenses if all the switches of a station compound are motorized and are operated collectively at one spot, the motorization of switches itself is fairly expensive.

At a station with simple track layout, it is advantageous and recommendable to operate it by a cable.

Heretofore, often used was the pipe line for switch operation. But now it is expected that the cable-system interlocking system will take the place of the old system with its attractive features of light and easy manoeuvre, low construction cost, less trouble in maintenance, etc.

VI. Signal and safety equipment for the new Tokaido-Line.

Following installations are on the planning board for the new Tokaido-Line (approximately 500 km between Tokyo and Osaka), which is under construction :

Since the ordinary track circuit can not be used, because the power system of the new line is the electric operation of 25 kV commercial frequency, the A.F. track circuit is to be used.

As for the signaling system, an automatic train control system will be installed with the cab signal of a continuous control-type. This system enables automatic control performance in case a train crew neglects to apply the brake in accordance with the speed control indicated by the cab signal device.

A train end indicator will be installed at the control center to indicate continuously the trains' position on the line.

The foregoing is the explanation of the Japanese National Railways' singularity in its transportation situations and the roles of its signal and safety devices as well as its creative engineering techniques. There are many problems charged to the railroad engineers to be solved so as to retain the railway industry's position as a leader among various transportation means.

Facing to the urgent request of modernization of enterprise the mission we engineers have to carry out is momentous.

The true self of the Japanese National Railways is evident in its constant progress which has been achieved by its tireless efforts amid of such present situations.

[625 .172 (52)]

Statistical control of track maintenance,

by Jiro ONOGI.

(Japanese Railway Engineering, June 1960.)

1. Preface.

The subject of this paper concerns a method of control of maintenance of track making use of statistics and probability theory. The method is still in embryo in respect of practice, and it will take some time to develop and systematize it. Readers are requested to bear in mind that this paper deals with its rudimentary problems only.

In the maintenance of track, it is most fundamental to know what the structure of track is and what mechanical action the track receives from the train load. Many predecessors made studies in this regard, and recently, it has been brought out that the primary factor in the destruction of a track is its vibration caused by running trains. Thus the approach to the problem is given a definite direction. On the other hand, a track is usually laid as a mechanically incomplete structure because of economic reasons so it is constantly exposed to the destructive action of train loads. Accordingly it has to be repaired, or its components have to be replaced, by putting in labor and materials. It is also important to determine how the employment of labor and materials can be controlled in a proper way while keeping trains safe and comfortable. This, combined with the problem of track structure, constitutes a basic consideration in the maintenance of track.

The rule governing the phenomena in the structure of track is the law of cause and effect in terms of mechanics. However, the employment of labor and materials cannot be controlled by this law alone. It is not absolutely impossible to mechanically determine, for instance, the phases of track deformation by the rules of mechanics. However, it may be regarded impossible from the standpoint of practice because of a number of limiting factors. Another example is rail failure. Notwithstanding the fact that it should be an object of study based on mechanics, a rail failure cannot be foretold with reasonable accuracy through analysis based on mechanics.

If the field of the problem of track structure is named « field of gravity », it may be said that there are many « fields of probability » in the problem of control of track maintenance. Speaking of the existence of track deformation mentioned above, for instance, if a rule governing the probability of existence of track deformation is found out, it would be possible to know the phases of track irregularity of a section, though exact knowledge of the irregularities of specific points would not be made available. Also, a probability of occurrence of rail failure could be derived from an accumulated knowledge on span of life of rails based on statistics of rail failure covering a very long period. These are very useful in the control of track maintenance. Occurrence of natural disasters, including operation accidents, is entirely a matter of chance. It should be handled in the light of sheer probability.

As seen in the foregoing, the control of track maintenance should be handled on the basis of probability or statistics, while observing the phenomena from the rules of mechanics. A few examples of statistical treatment are given below.

2. Statistical representation of track irregularities.

One of the most important points of observation in setting up a track maintenance plan is the state of destruction or deformation of track. However, it is of little

use for a long stretch of track to have an information on the deformation of each point of track. Let us take a track, for instance, on a section of a certain length. Even if the state of the track deformation is measured by a track inspection car and a chart covering the whole section is derived, it will be nothing but a vague knowledge lacking a means of expression to embody proper quantitative determination, which should be the very indication desired. Broadly speaking, the number of points on a section of track may be regarded as infinite in observing the state of deformation of a track extending over a distance. It means that a method of expression capable of providing for the state of deformation in infinite numbers is called for.

On the Japanese National Railways the practice is to express the deformation of track in four kinds of irregularity, i.e. irregularity of gauge, cross level, track level and alignment, giving a general term of the track irregularities. The definition of track irregularities is given at the end of this paragraph. It has already been found out that the state of track irregularities to various extents follows a rule on a section, on account of the nature of track irregularities as defined above. This state does not determine the extent of track irregularities significantly, but means the ratio in which track irregularities of various magnitudes exist on the section. The fact that the track irregularities conform to a rule would be very convenient in obtaining data on track condition on a section, even though the number of such irregularities may be infinite. Once it is known that the state of existence of track irregularities follows the law of probability, now there will be no need for consideration about infinite track irregularities in order to know the state of the section of track. Instead, measurement of a proper number of track irregularities in a section in question as a whole will be sufficient. The rule governing the state of existence of track irregularities is considered to be a law of probability called the normal distribution. The justification of this view is given by actually measuring the track irregularities on a section.

The fact that the state of existence of track irregularities follows the normal distribution leads to the appropriate method of indication of track condition as described below.

Let x denote the magnitude of track irregularity of a section, and $\Phi(x)$ the ratio in which there are track irregularities smaller than x in magnitude; then by the nature of normal distribution,

$$\Phi(x) = \int_{-\infty}^{x} \frac{1}{\sqrt{2\pi}\,\sigma} e^{-\frac{(x-m)^2}{2\sigma^2}} dx \qquad (1)$$

The two parameters, m and σ, on the right side are what we call the mean value and the standard deviation, respectively. Their values are given as follows : Let us measure n pieces of track irregularities, and put the magnitude of individual irregularities as x_i ($i = 1, 2, \ldots, n$).

Then,

$$\left.\begin{aligned} m &= \sum_{i=1}^{n} x_i / n, \\ \sigma &= \sqrt{\frac{\sum_{i=1}^{n} x_i^2}{n} - m^2} \end{aligned}\right\} \qquad (2)$$

Since the value of $\Phi(x)$ is determined when m and σ are made definite to a given x, the values of m and σ represent the characteristics of the section. Figure 1 is the graph for :

$$\frac{1}{\sqrt{2\pi}\,\sigma} e^{-\frac{(x-m)^2}{2\sigma^2}} .$$

m giving the center abscissa for the curve, and σ indicating the degree of extent of the curve, i.e. the extent dispersion degree of track irregularities. The area of the hatched part is $\Phi(x)$. The values of m and σ, though given by eq. (2), were, in fact, statistically derived. The actual values of m and σ must be determined on the condition of $n = \infty$. However, since they also conform to a law of probability, values

accurate enough for the purpose are obtained through eq. (2), by giving an appropriate number to n. It has been disclosed that accuracy is satisfactory when n is 120 to 200 per kilometre if measurement is made evenly over a section of a fairly normal condition as far as the purpose of the control of track maintenance is concerned.

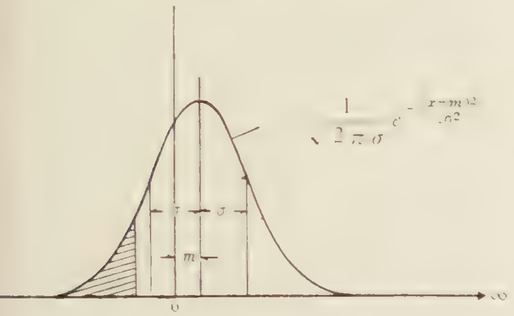


Fig. 1. — Normal distribution curve.

It is sometimes inconvenient to use more than one index, while the state of track irregularity of a track section of a moderate length is made clear by applying m and σ. On the JNR, therefore, the value given by the following equation is called the track irregularity index.

$$P = \left\{ \int_{-\infty}^{-a} \frac{1}{\sqrt{2\pi}\,\sigma} e^{-\frac{(x-m)^2}{2\sigma^2}} dx + \int_{a}^{\infty} \frac{1}{\sqrt{2\pi}\,\sigma} e^{-\frac{(x-m)^2}{2\sigma^2}} dx \right\} \times 100 \quad (3)$$

As seen from eq. (1), P indicates the percentage of the track irregularities of which the absolute value is larger than a. A single value of P corresponds to the values of m and σ worked out, and, as such, indicates the state of the track. According to the JNR practice a is fixed at 3 mm, because it is most suitable for the indication of the state of tracks. However, some other values may be adopted to suit the existing conditions of track and the objectives of control of track maintenance.

Note : Definition of track irregularities.

Irregularity of gauge.

The magnitude of deviation of minimum distance between the right hand and the left hand rails at 16 mm below rail level, from the standard (1 067 mm). Widening is marked (+), and narrowing, (—).

Irregularity of cross level.

The difference in height of the right hand and the left hand rails. The mark, (+), is shown when the standard side is low, and (—) when it is high. The standard side is the left hand for a straight track, and the inner rail for a curve.

Irregularity of track level.

A 10 m long string is pulled tightly along the rail level, with the measuring point at the center, and the distance between the string and the rail level at the center is to represent the track level irregularity. The mark, (+), is given when the rail level is higher than the string, and (—) when it is lower.

Irregularity of alignment.

A 10 m long string is pulled tightly alongside the rail head, with the measuring point at the center and the distance between the side of the rail and the string at the center is to represent the alignment irregularity. The mark, (+), is shown when the string is outside the track, and (—) when it is inside.

In measuring a curve the magnitude of slack, superelevation and maintenance barsine is subtracted from the value of track irregularities.

3. Control of track maintenance by control chart.

If the state of track irregularities is quantitatively determined by the method men-

tioned in section 2, various hints for the control of maintenance will be derived from the characteristic values of a given track section of a suitable length. Since those characteristic values are statistical figures, a different statistical method of handling them is possible. This is what is called Shewhart's quality control chart method, which is widely applied to the control of industrial products. Though not in the prototypical way, in view of difference of

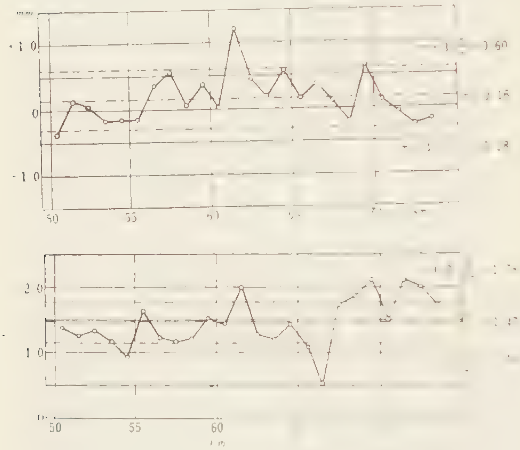


Fig. 2. — m-σ control chart (cross level).

nature of industrial products and track irregularities, it is applicable to the latter under careful interpretation. For example, it is possible to study whether several sections (1 km each, or each under charge of a track gang) of a track are maintained in uniform condition (if the condition varies, the control of track maintenance is not good) by using an m-σ control chart as shown in figure 2. Figure 2 is a control chart for the irregularity of cross level per kilometre, where the abscissa represents kilometrage and the value of m and σ is plotted every kilometre. The upper section is m-chart, and the lower is σ-chart. In each section, the upper and the lower dotted lines indicate control-limit values, and the chain line located at an equal distance from the upper and the lower limit-line is drawn at the height representing the mean values, m and σ, of m and σ at every kilometre on the section. The letter n contained in :

$$3\,\frac{\bar{\sigma}\,cut}{\sqrt{n}} \text{ and } 3\,\frac{\bar{\sigma}\,cut}{\sqrt{2n}},$$

which give the distance from the mean value line to the limit-line, represents the number of measuring points per kilometre. In the present instance the chart is drawn with $n = 100$. The control chart method makes use of the fact that the characteristic values indicating such a state as m or σ follow a law of probability. It is known that the values of m and σ for each kilometre we obtained by actual measurement are to be within the limit determined from the law of probability mentioned above, if the track condition is uniform over the section we picked out, from 50 to 75 km, that is, if there are no differences between m and σ over the section. Therefore, the values of over-limit-line in m-chart or σ-chart are statistically rare happening, and in practice, such a section having m or σ of over-limit-line is regarded as abnormal. The benefit of using a control chart is that it enables us to check such an abnormal section and thereby find out what action would be necessary.

Another use of a control chart is to know whether the tracks in general in a wide area are in good condition or not. The example of figure 2 is virtually a direct application of Shewhart's method. In the case of a control chart for much larger sections (e.g. railway divisions), a different kind of control chart may be more suitable, so a control chart appropriate for the purpose of control and for the characteristic values used must be worked out. Figure 3 is a control chart using P to have a picture of irregularity in cross level of trackage of railway divisions of the Japanese National Railways for a certain period. This chart is called the x-Rs control chart, the upper section being x-chart and the lower, Rs-chart. In each section, the abscissa represents railway divisions. The ordinate in the x-chart takes values of P, and the same in the Rs-chart takes absolute value of the

difference between the value of x for the railway division given by a point on the abscissa and the value of x for the railway division adjoining next on the left. (In the case of the left-most railway division, the difference is taken by comparing with the

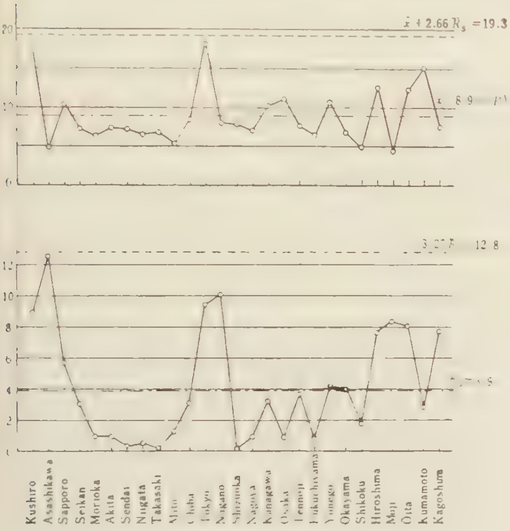


Fig. 3. — x-Rs control chart.

right-most railway division.) « Rs » is what is called the range, and plays the part of σ which does in figure 2. Like the m-σ control chart stated before, the x-Rs chart enables the marginal lines to be determined from the law of probability as to x and Rs, thereby making it possible to check the values of P.

Strictly speaking, the application of a control chart (*) method to the track maintenance control is often attended by difficulties. But, as far as the detection of abnormal values is concerned, it may safely be applied.

4. Statistical analysis of various factors in maintenance of track.

The idea of employing control charts consists in the detection of the abnormal values as brought out by a limit line which is statistically established. However, the determination of causes for the occurrence of such abnormal values calls for a separate knowledge. Factors having effect on the state of track broadly comprise train load, track structure, climatic conditions and labor. The law of cause and effect existing among them is to determine the condition of track. The aforementioned four factors are further divided, and it is extremely difficult to analytically establish rules governing such basic factors. Here also arises the need for a statistical method.

Some statistical means of investigating the effects of various factors on a phenomenon have already been systematized as the design of experiment with satisfactory results. The possibilities of such methods are expected

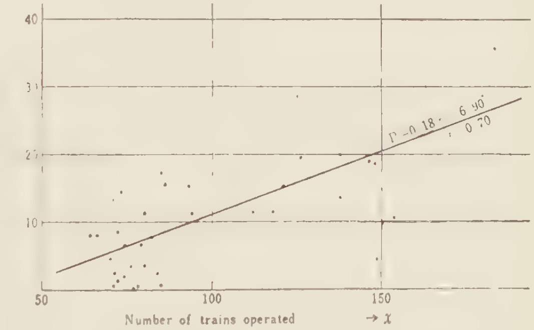


Fig. 4. — Relation between P and number of trains operated.

to show up also in the analysis of factors governing the track. The design of experiment, originally developed from agricultural experiments, is well applicable in so far as it is easy to handle the factors purposefully. In the case of railway track, however, it is

(*) For the details of the control chart method, readers are requested to refer to the following literatures :

— American Society for Testing Materials : ASTM. Manual on Quality Control of Materials, 1931.
— J.M. JURAN : Quality Control Handbook, 1951 (McGraw-Hill).
— W.A. SHEWHART : Economic Control of Quality of Manufactured Product, 1951 (Van Nostrand).
— British Standard, 600 R, 2564.

not easy to fix the conditions of the experiment, so it calls for a special measure, as in the case a control chart is used. This is a point yet to be developed. However, not rarely is it possible that an expected result is obtained by statistical techniques, such as analysis of variance and covariance. Figure 4 indicates the correlation between the train frequency and the index P for cross level irregularity. The ordinate gives the values of P for track gang sections for a period on the Tokaido Line (the most important trunk line on the JNR), and the abscissa, the corresponding number of trains daily operated. It may be inferred from the figure, by just having a look at the distribution of points, that the values of P increase roughly with the number of trains. However, since each point has fluctuation including some considerably detached values, no definite judgment by a simple observation could be justified. On the other hand, analysis of covariance would make it possible to linearly express the mean values, as shown in figure 4, while the values of P have fluctuations corresponding to the number of trains. Showing that the correlation coefficient $r = 0.70$ means that the linear relationship is fairly accurate.

5. **Conclusion.**

Thus far the exposition has been made with the statistical handling of track irregularities as an example.

The statistical means is useful in not a few cases concerning materials, labor or funds as well as track irregularities. As stated at the beginning, the development of methods of statistical control is, for the most part, a future problem. This paper has restricted itself merely to laying stress on the usefulness of the method. Readers are requested to recognize the fact that there are not much available data to serve as reference in the practice of maintenance of track.

[385 (09 .2]

OBITUARY.

Brigadier John Aiton BELL, C.B.E.

Former General Manager of the East Indian Railway.

Former Member of the Permanent Commission of the International Railway Congress Association.

We have learnt with great regret of the death on the 19th November last of Brigadier John Aiton BELL, former General Manager of the East Indian Railway and former Member of the Permanent Commission of our Association.

Born in 1887, J. A. BELL was appointed to the Indian State Railways service as an Engineer in 1910. He remained in India up to 1939, occupying successively various important posts.

He left India to rejoin the British Army, and during the 1940-1945 war he was Director of Railways, 21st Army Group.

Mr. BELL was appointed Member of our Permanent Commission in July 1939 and he participated during the same year to the Enlarged Meeting of the Permanent Commission in Brussels. He showed the greatest interest in the work of our Association. His affability of character gained him the sympathy of all his colleagues.

We offer to his family our sincere condolences.

The Executive Committee.

NEW BOOKS AND PUBLICATIONS.

[385 (08 (45)]

Direzione Generale, Ferrovie dello Stato. *Relazione per l'anno finanziario 1958-59 et Dati analitici complementari alla Relazione per l'anno financiario 1958-59* (*Report on the year 1958-59 and Additional Statistical data to the Report on the financial year 1958-59*). Two volumes (8 1/4 · 12 in.) of 224 and 328 pages respectively, with numerous tables, graphs and figures. — 1960, Roma, Direzione Generale Ferrovie dello Stato, Piazza della Croce Rossa.

Under the titles « Relazione per l'Anno finanziario 1958-59 » and « Dati analitici complementari », two large volumes have been published by the General Management of the F.S. These documents, of pleasant appearance with a certain number of photographs and some maps, give an accurate impression of what the year under review meant for the Italian Railways. We can merely give a brief review of them here, taken from a summary in French issued by the F.S. under the title « Report for the Year 1958-59. — General review ».

Looking the facts in the face, the report begins by reporting a deficit, though a smaller one than that for the previous year; it amounts to 12.6 % of the net expenditure. The losses sustained do not mean, according to the report, that the railways are now an anti-economic means of transport, as the main lines of the system have always shown a profit. The report mentions some of the causes for the deficit : obligation to keep open lines showing a deficit; insufficient help from the State; tariffs maintained at a very low level for political reasons; the cost of pensions.

As in the past, the Administration has not ceased to modernise the installations. The works of electrification and doubling of the track have continued; the rearranging of stations on more rational lines and the renewal of the rolling stock are included in a five year plan which was begun in 1956-57. The Italian railways are progressively introducing long welded rails; 58 level crossings have been equipped with semi-barriers and refuge islands; palletisation has been increased; a special rail-road service has been introduced between Turin and Paris; the automatic checking of waybills and station accounts has been centralised at Turin, where an electronic calculator has been put into service.

As regards competition from other methods of transport, the number of passenger motor vehicles has remained approximately the same, except in the case of motorcycles, which have greatly increased in numbers; air transport appears to have a traffic, estimated in passenger-km, corresponding to 2 % of the railway traffic, whilst the capacity of motor lorries has increased by 3.2 %.

The passenger traffic, estimated in train-km and passenger-km has slightly increased; the gross receipts from this traffic amounted to 51.3 % of the total traffic receipts. The goods traffic showed a slight decline; its receipts represent 46.4 % of the total. The remainder of the receipts, i.e. 2.3 % came from the luggage service.

The number of staff of all categories amounted at the end of the year to 193 728, i.e. a reduction of 4.22 %.

Steps to abandon lines showing a deficit by replacing the train services by other methods of transport always come up against numerous difficulties : during the year in question this could only be done effectively on 8 km of standard gauge and 240 km of narrow gauge lines. On the

other hand, the State subsidised the construction of 45 km of new lines. In the sphere of electrification, 397 km of single track and 28 km of double track were equipped with catenaries.

The stock of coaches and wagons for standard gauge slightly increased (2.5 %), whilst that for narrow gauge (total extent of such lines : 347 km) diminished considerably.

As regards the ferry-boat services across the Straits of Messina, a new unit, the « Reggio » (with 340 m of useful track) is under construction; the new boat will join early in 1960 the five other boats already in service here. Two other boats are on order for use on the Sardinia line, the working of which has just been handed over to the F.S.

The annual report also mentions the construction of many houses for the staff : 738 flats in Rome and 857 in various other localities; within the framework of the public building programme, 916 additional apartments have been completed and rented to railway workers, whilst 939 others are under construction. In addition, the Administration has begun to build in Rome an old people's home for railwaymen, financed partly by shares taken up by the staff itself. During the year in question, the staff also profited by an appreciable increase in wages and pensions.

The report (in the abbreviated French edition) ends with a concise analysis, in 4 pages, of the financial results for the year.

A. J.

[**385** (09 (45)]

CHEMINS DE FER DE L'ETAT ITALIEN — **FS. 59** (*The Italian State Railways*). — One volume (8 1 4 · 11 in.) of 100 pages with numerous maps and photographs in black and white and colour. — 1960, published by the Records Department of the Italian State Railways.

The Italian Railways have just published their report on the year 1958-59.

Like the previous reports, this commences by an analysis of the financial operation of the undertaking; the overall results are given, the repercussions of the general economic position of the country upon railway transport is examined, and the movement of supplies and orders for national industry.

The report then defines the general orientation of the commercial and economic policy of the railway and deals at length with the question of tariffs, as well as that of long distance bulk transport. It also stresses the value of collaboration with other European railways and proper coordination with road transport.

Numerous graphs and statistics illustrate the progression and improvement in the traffic position. The quality of the services offered to clients both in the passenger and goods fields is evaluated on a realistic basis.

The achievements during the year 1958-59 in all fields of railway technique are also the subject of a detailed report : electrification, permanent way and bridges, improvement of the rolling stock, studies and trials...

An important chapter of the report is devoted to the education of the staff, automation, the organisation of the work and increase of productivity, as well as to social matters.

It ends by reporting the bold projects to be put in hand during the next few years.

R. S.

[**385** (09 .3]

BERGHAUS (Erwin). — **Auf den Schienen der Erde. Eine Weltgeschichte der Eisenbahn.** (*On the rails of the world. A world history of the railway.*) — One volume (6 × 8 3/4 in.) of 368 pages with 107 photos, 19 drawings, 16 maps and 10 tables. — 1960, Munich, 3 Schliessfach, Süddeutscher Verlag, Buchverlag, Sendlinger Strasse 80. — (Price : bound in cloth, DM 27.30.)

The author, having collected a very abundant documentation taken from the most diverse sources, has taken pains to make his work, subtitled « World History of the Railway », interesting to read, without superfluous technical details, but full of historical facts and anecdotes.

From the very beginnings down to contemporary times, the multiple aspects of railway operation are dealt with. The work follows step by step the development of the railway from the birth of the « iron horse » in the English mines to the completion of the European network, which has taken the continent over to a new type of economy and revolutionised the life conditions of everyone. The author shows likewise how the railway has been a powerful ally of American industry, and in particular how it has made possible famine relief to India, the development of African territories and the industrialisation of Japan.

The improvement in comfort and safety, the increase in the average speeds, thanks to electrification, dieselisation and the use of electronic devices are gone into at length.

Complete chapters are finally devoted to those railway activities with which the public is less familiar.

This book, which in addition is copiously illustrated, is sure of a favourable reception from all those who for various reasons are interested in the past and present history of the railway.

W. v. R.

[**313 : 656** (494)]

Schweizerische Verkehrsstatistik, 1959 (*Swiss Transport Statistics, 1959*). — One volume (8 1/4 × 11 1/2 in.) of 174 pages with numerous tables and 5 graphs appended. — 1960, Berne, published by the Federal Transport Office. — (Price : 15 Swiss francs).

The *Federal Transport Office* (Berne) has just published (November 1960) its annual « Swiss Transport Statistics », which make it possible to get a general picture of the evolution of transport from one year to another.

If the year 1958 saw a certain decline in the general economy and in railway goods traffic, 1959 on the contrary showed a recovery, especially during the second half. The tonnage of imports and exports reached a new record.

On the 1st October 1959, the passenger tariffs of the C.F.F. were slightly increased, but a decree obliged the other railways to bring their tariffs in line with those of the Federal Railways. In spite of this increase, other undertakings were able to reduce their transport rates. Together with the enormous increase in foreign visitors, all this led to a remarkable increase in the passenger traffic. As for the goods traffic, this increased by 6.5 % on the C.F.F. and 9.6 % on the private railways. Thus the operating coefficient of the Federal Railways amounted to 89 % (compared with 89.2 % in 1958), whilst in the case of the private railways, it was 99.3 %

(compared with 101.4 % for the previous year).

We might also point out in passing that the average journey length was the fairly satisfactory one of 102 km.

The special railways, less affected by road competition, profited to the full from this situation. Nine new installations were carried out during 1959 and others are to follow. However, the financial situation is not so brilliant : more than one quarter of the 93 undertakings ended with a deficit.

In the case of tramways, motorbuses, etc., the increase in traffic was only 1 %. During the year, 20 km of tramways were replaced by buses or trolleybuses.

In the case of the road, the number of vehicles, which increased by some 70 000, is now more than 800 000. To this traffic must be added the foreign cars and motorcycles, more than 17 million of which visited Switzerland during 1959.

There has been an extraordinary increase in international goods traffic by road : the tonnage has increased more than fivefold since 1951 in the case of imports, whilst in the case of exports it has increased nearly six times. During the year in question, it increased by 32.8 % in the case of imports, and 66 % in the case of exports. The statistics give details of the kinds of goods concerned.

Navigation on the lakes increased by 15 % in the case of passenger traffic. Traffic on the Rhine fell off, owing to the low level ot the river since September.

Air traffic (Swissair) once more increased by 3.5 %, a figure lower than the increase for the previous year.

The work ends with various extremely interesting graphs and a map of the funicular and telpher lines.

P. Sch.

] **656** .2]

Chemins de fer (*Railways*), special issue of the quarterly review *Science et Vie* (No. 53). — A pamphlet (6 3/4 × 9 1/2 in.) of 160 pages, copiously illustrated. — 1960, Paris (8e), *Science et Vie*, 5, rue de La Baume. — (Price : 3 NF).

The most recent special number of the review *Science et Vie* is devoted entirely to the railway and to some extent deals with the most recent innovations since a similar issue appeared in 1952.

In the editorial, Mr. Ph. DARGEOU, General Manager of the S.N.C.F., declares : « The railway is one of the great links between science, which makes its progress possible, and modernisation, and the economic life of the country to which it makes such a powerful contribution ». The present issue shows in effect that if the railway is in full evolution in every sector, such evolution is taking place without losing sight of the fact that its essential mission is to serve the community.

In an important article : « The railway artisan of European integration » Mr. DE Vos, General Manager of the S.N.C.B., makes it clear that the railway was one of the first to promote the evolution of the peoples towards better collaboration. The various international organisations set up by the railway systems for the exchange of information may be quoted as an example to an Europe endeavouring to achieve unification.

After a history of the rail, fully documented and illustrated, various articles deal with the progress achieved both in the case of the permanent way and Diesel and electric traction, and in that of safety, traffic and management.

The new stage the permanent way department is now covering concerns essentially the mechanisation of maintenance work, the laying of long welded rails and

mechanised checking of the condition of the track.

After the era of D.C., electric traction has deliberately swung over to industrial frequency A.C. This new orientation has led to the creation of multi-current engines allowing of the joining up of networks having a different system of electrification without having to have multi-voltage stations or changing locomotives. At the same time, the substations have also undergone considerable evolution and are already profiting by telecontrol to adjust the running of the installations to the traffic requirements.

Important developments in Diesel traction and the special features thereof are also reported.

An increase in safety has been brought about by the use of electric devices and telecontrols and checks, different examples of which are given.

In addition electronic management is the subject of an article by Mr. R. HUTTER, Manager of the Research Department of the S.N.C.F. The electronic machine acquired by the S.N.C.F. will not only supply all necessary data concerning the movement of wagons, movement of trains, and the management of the stock, but also get out the wages due to employees, carry out the work of the Insurance Office, pensions office and statistical and commercial accountancy work as well as making it possible to carry out scientific research work.

A final article is devoted to the evolution of the Metropolitan Railway.

W. v. R.

MONTHLY BIBLIOGRAPHY OF RAILWAYS (1)

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General Secretary of the Permanent Commission of the International Railway Congress Association.

(APRIL 1961)

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